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Metal Progress

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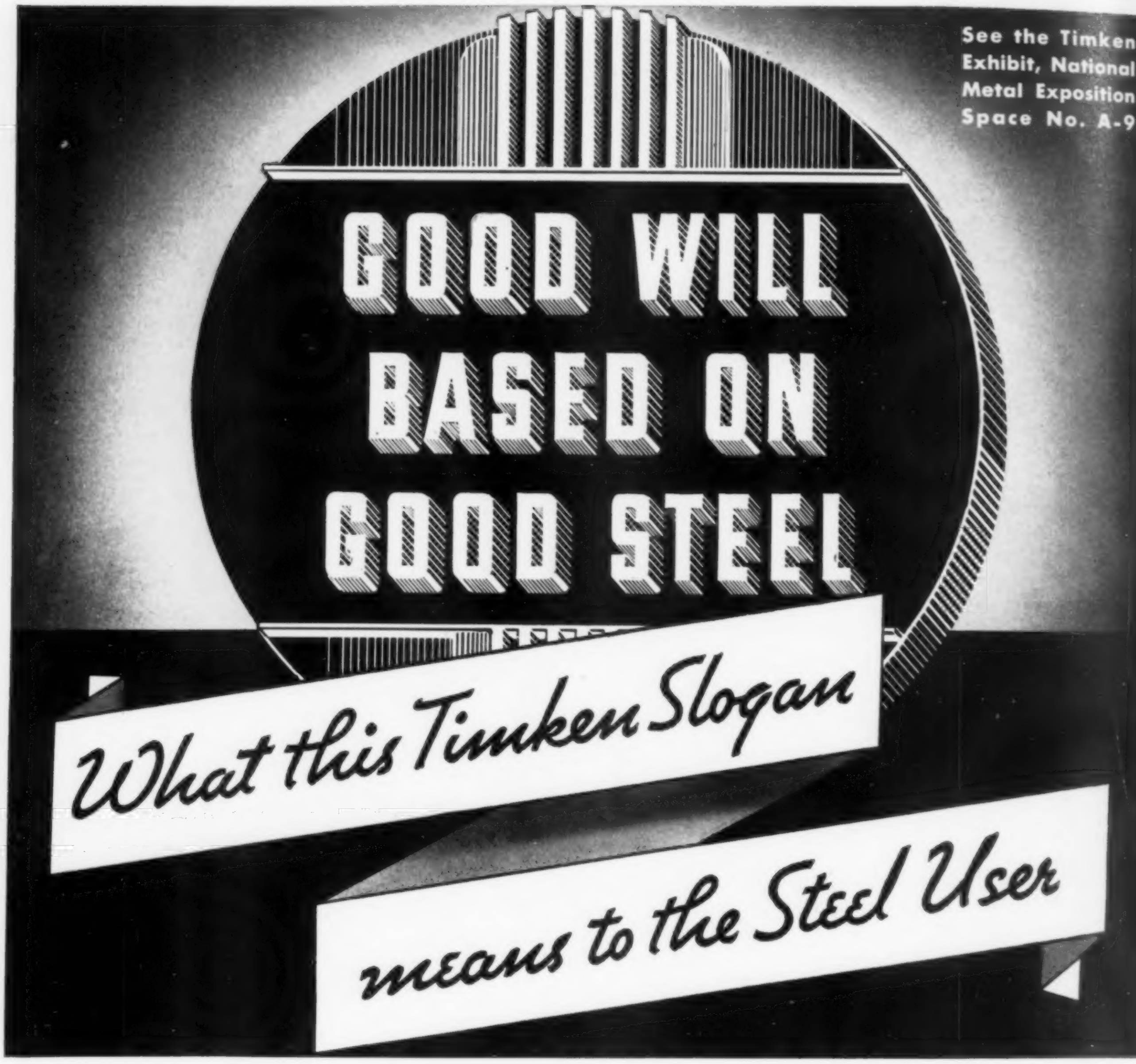
Ernest E. Thum, Editor



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METHODS AND SUPPLIES

Operations in Controlled Atmospheres Have Been Topics of Interest for Years —Note Numerous Issues of Metal Progress Since 1930—But This Section Tells of a Recently Built and Very Cleverly Designed Unit for Automatic Hardening

SHAFTS OF 1040 STEEL HARDENED FROM CONTROLLED ATMOSPHERE

MANUFACTURE OF SHAFTS FOR automobile shock absorbers of the hydraulic type utilizes the recently acquired information about steels with controlled grain size. They are also heated in precisely controlled atmospheres. The present process avoids serious difficulties encountered in the past, and may shed light on similar or related problems in other fields.

As is probably well known, a hydraulic shock absorber is essentially a dampening device attached to a leaf or coil spring. As the spring depresses or rises above normal height, oil is forced from one chamber to another through a small orifice, and the resistance offered by this fluid flow absorbs enough energy to bring the oscillating spring to rest after a comparatively few oscillations. Various machine elements, like lever, shaft, cam, bearings and piston, are required to transfer the forces from spring shackle to oil chamber.

One of these mechanical elements is the shaft in question. Various designs of shock absorbers are in production, and this part may therefore be anything from ¾ in. diameter by 3 in. long to 1.016 in. diameter by 10 in. long. Representative examples are photographed on the next page. Their essential parts are ribbed areas (where levers or cams are pressed on) and ground journals. The shorter, stockier shafts are used on the single-action type of shock absorbers, made since the beginning. These were hardened satisfactorily in routine production, but difficulties appeared with the long shafts for the double-action, knee type shock absorbers designed to work with independently sprung wheels. In this article attention will be confined to long shafts, it being understood that the practice was developed with a background of information acquired in several years' production of the shorter shafts.

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These shafts are made of S.A.E. 1040 steel, which when water quenched will give Rockwell C-55 to C-62 hardness, sufficient for wear resistance in the bearings. The job is made in screw machines; cold drawn bars are used for their uniformity of size and machinability. When first put into production, they were hardened in a pusher type of furnace; the workman laid the shafts out in grooves in the trays, and at the discharge end the trays were tilted so the shafts slid end-on into a water tank, six feet deep.

This practice when applied to the longer shafts gave large losses in production. About one-third of them would be warped more than the tolerance for straightness (plus or minus 0.005 in. at center, shaft turned on vee blocks at ends). These would then be straightened, but if the steel were of a deep hardening variety, most of them would break under the press. In that case it was necessary to anneal the shafts before straightening and then reharden. Even if the steel were shallow hardening and could be straightened, that operation should be avoided wherever possible, for it does not improve a quality product.

Difficulties also arose from the variable amount of scale. In both the deep and shallow hardening steel, an unduly thick patch of

oxide would prevent a rapid quench and a soft spot underneath would be the result. Bunching in the quench tank also caused some variations in the hardness, so that constantly rising standards could not be met. Furthermore, the scaled ribs had to be wire brushed to remove any particles of scale that might be present. It rapidly became apparent that some scheme must be worked out which would eliminate warping certainly, and would also prevent scaling if possible.

An analysis of the heating and quenching operation indicated that a part as symmetrical about its longitudinal axis as one of these shafts should come out of the quench quite straight if it were properly supported during heating, heated uniformly without scale, transferred to the quenching medium without striking anything, and quenched vertically and uniformly on all sides. Such a program was put in practice by placing the shafts vertically in a rack, heating them in cyanide, withdrawing them one by one with tongs, and dropping them down a 1½-in. pipe 5 ft. long, against a rising stream of cold water.

These shafts so treated were clean, without scale, and the amount of straightening required was reduced materially (but not entirely, due to rough handling or carelessness of workmen in the quenching operation). It was also found that a warped shaft could not be straightened unless annealed, due to the brittleness set up by the nitrogen case imparted from the cyanide bath.

Representative Examples of the Shaft to Be Hardened. The ones with the counterbored ends were especially troublesome when made of deep hardening steel, for these ends were expanded and welded to an arm after assembly, and a large proportion would then crack

For large production of the longer shafts for double-action shock absorbers, this needed a number of cyanide pots operating 24 hr. per day, which resulted in high furnace maintenance, heavy personnel turnover, and high cost per finished shaft. The worst thing about the process, however, was that the hardness on the bearing journals was not uniform. It is well known that cold drawn rod is slightly decarburized on the surface (due to the method of heating billets and bars in the hot rolling mill). This decarburized skin is of variable thickness, and it was found impossible to recarburize it successfully on the unmachined portions of the shaft, even when using 45% cyanide baths energized with considerable 90% cyanide salt. Consequently, a rather large allowance had to be ground off to get down to the 0.40% carbon metal, and even then, this was liable to be insufficiently hardened. (This experience checked that with the shorter shafts, hardened in baskets in cyanide, and dumped batch by batch into a well-baffled water tank; uniform hardness always seemed to be "just around the corner"!)

About this time, the importance of grain size control was brought forcibly to our attention by a large proportion of failures in one design of our short shafts. As shown in the engraving, one end is counterbored so that when the lever arm is pressed on, the hollow end of the shaft can be expanded and welded to the hub of the arm by an operation in a resistance welder. If such a shaft is made of a coarse grained, deep hardening steel, the thin walls at the counterbored end will harden clear through and crack either in the hardening process, or when pressing on the lever arm. This was cured by ordering only S.A.E. 1040, grain size 6 to 8 by McQuaid-Ehn test.

One of Several Hooded Cyanide Pots Used for Hardening the Longer Shafts. Observe fixture, partly loaded with shafts, to hold them vertically during the heating

(In passing, it might be remarked that the McQuaid-Ehn grain size is that achieved during carburizing at 1750° F., whereas these shafts are never hotter than 1500 or 1525° F. Therefore the grain size should be determined at a temperature slightly below the A_3 range, that is, the heat treating range as suggested by Bain and Davenport. Essentially we want an inherently fine grained, tough, shallow hardening steel in the finished part.)

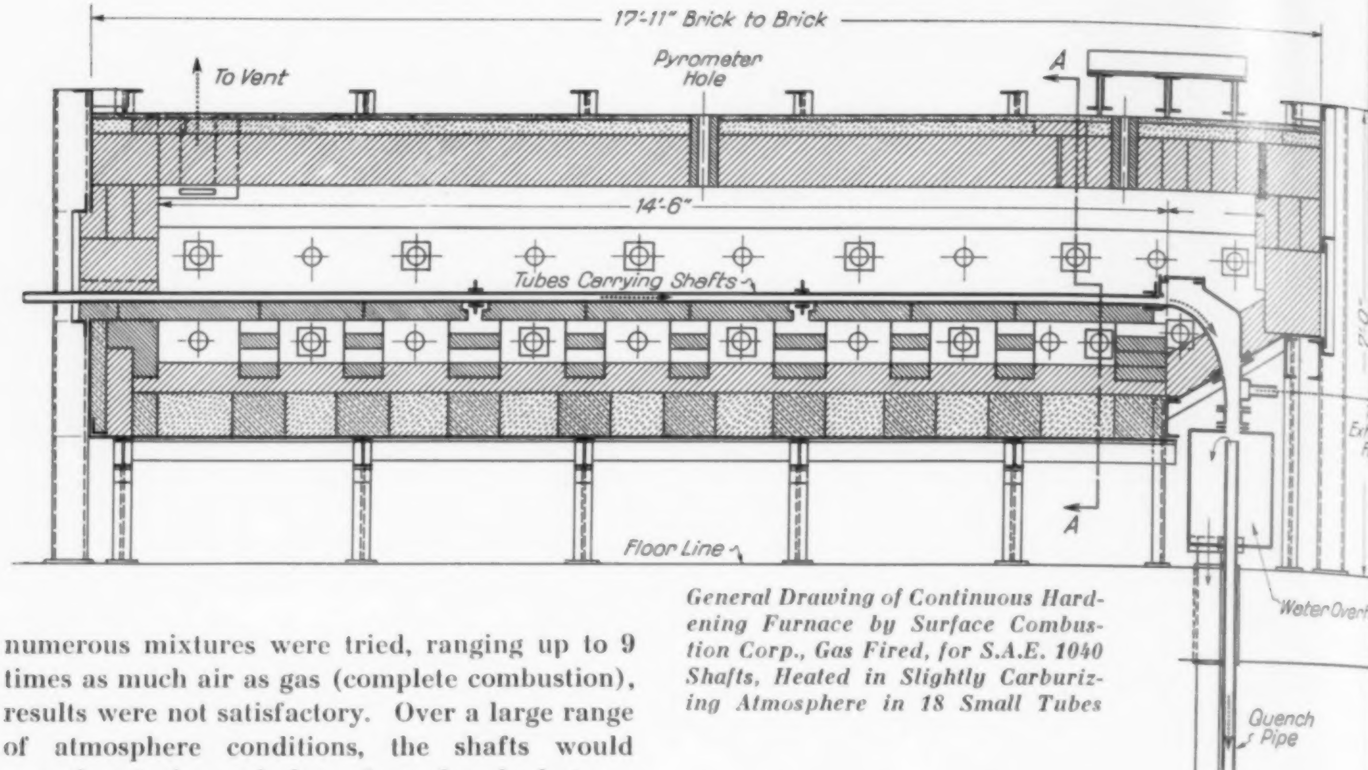
We therefore started the manufacture of long shafts with steel of controlled grain size at about the same time we turned attention to a hardening furnace with atmospheric control. Our experiments with various methods of quenching — especially in long water pipes — indicated that variable scale would influence the uniformity of hardening enough to pull the shafts out of line, so we worked out an atmospheric control for reducing this oxide to zero. Naturally, we did much preliminary work on a small scale, guided by experience in the tool hardening department, with furnaces of the Hayes "Certain Curtain" type, and experimental muffle furnaces capable of precise atmosphere control.

A first attempt was made with raw gas in a high nickel alloy tube. The gas is 1050-B.t.u. natural gas of the following analysis: CH_4 93.7%, C_2H_6 2.9%, CO 1.9%, O_2 0.7% and N_2 0.75%. It is of such a nature, and the catalyzing action of the high nickel tube at 1500° F. is such that cold gas would "crack" and deposit much carbon, which not only would cling to the shaft, interfering with the quench and constituting a cleaning problem, but in short time actually plugging up the tube with carbon soot.

This sooting problem was solved by two expedients. Tubes are now made of lower nickel sheet, bent to shape and welded longitudinally (either low carbon 18-8 with 2% silicon, or another alloy containing about 25% chromium, 11% nickel). These tubes are set in a long furnace with a considerable temperature gradient, and the gases are introduced at the cool end, working their way gradually through and apparently undergoing some stabilizing reactions at the lower temperatures, as indicated in the curve on page 10, which represents a temperature-analysis survey of the conditions in the heated tubes, when filled with work, end to end.

With this longer tube furnace available, trial runs were made with gas "preformed" in a separate unit — that is, the natural gas would be partially burned in given quantities of air, dehydrated to certain humidities, and passed through the hot tubes with the work. Although

First Quenching Devices for the Longer Shafts. Shafts are posed as they enter sleeve guiding them into top end of pipe, where they drop down through a rising column of cold water



General Drawing of Continuous Hardening Furnace by Surface Combustion Corp., Gas Fired, for S.A.E. 1040 Shafts, Heated in Slightly Carburizing Atmosphere in 18 Small Tubes

numerous mixtures were tried, ranging up to 9 times as much air as gas (complete combustion), results were not satisfactory. Over a large range of atmosphere conditions, the shafts would quench out nice and clean, free of scale, but unfortunately not hard enough. Apparently what was needed was a protective atmosphere that would slightly carburize, and this could not be formed simply by partial combustion of our gas in a separate unit.

It was suggested that a gas-air mixture be introduced into the furnace tube *with* the work. This in fact has solved the problem — not without some false starts, however. If the gas entrance is placed at the discharge or hottest part of the tube, there is liability of coking, and also the uncombined oxygen coming into contact with the hot shafts causes scaling. (As little as 0.5% air will scale the shafts.)

Gas-Air Mixture Introduced With Work

The successful plan introduces air-gas mixture (1 part air to 1 part gas) into each tube near its entrance end. A considerable excess is used, so that a flame burns at the mouth of each tube. The far end (hot end) opens into a hopper-like casing, and a light suction of about 0.1 in. water pressure is induced by a fan leading from the back wall of this casing. In this way, it is insured that no air will be drawn in with the work, or through the seals where tubes connect to unloading hopper in the furnace combustion chamber, and the prepared atmosphere will move slowly forward from colder to hotter regions with the work. In this way, the relation of CO, CO_2, and the remaining hydrocarbons is controlled as shown in the diagram (page 10); at least it is controlled under far better conditions than in an openhearth type of furnace where a struggle toward equilibrium is going forward at three regions — at the relatively cool inlet, the glowing resistors, and the surface of the metal being heated.

The shafts after heat treatment are the color of mill scale on all unmachined surfaces, while the machined surfaces are the color of cold drawn steel. Enough carbon is added to the unmachined areas so that a minimum amount of grinding (0.006 in. on radius) prepares a uniformly hard surface of an average Rockwell C-58.

As shown by the drawing, the furnace contains 18 tubes, 1¼ in. diameter, and about 16 ft. 4 in. long. Each tube has a pusher lever in line at the entrance; the levers are operated in synchronism and in proper order by cams from a single drive shaft. Temperature gradually reaches heat (1500° F.) about two-thirds through the furnace. Speed of pusher is adjusted so each shaft takes approximately 8 min. to pass through the last third of the furnace soaking at 1500° F.

Temperatures are controlled at two points in the furnace, one near midlength and the other near discharge end. The preheating zone receives all the products of flame combustion from the 22 burners, vents being placed in the arch near the front end wall.

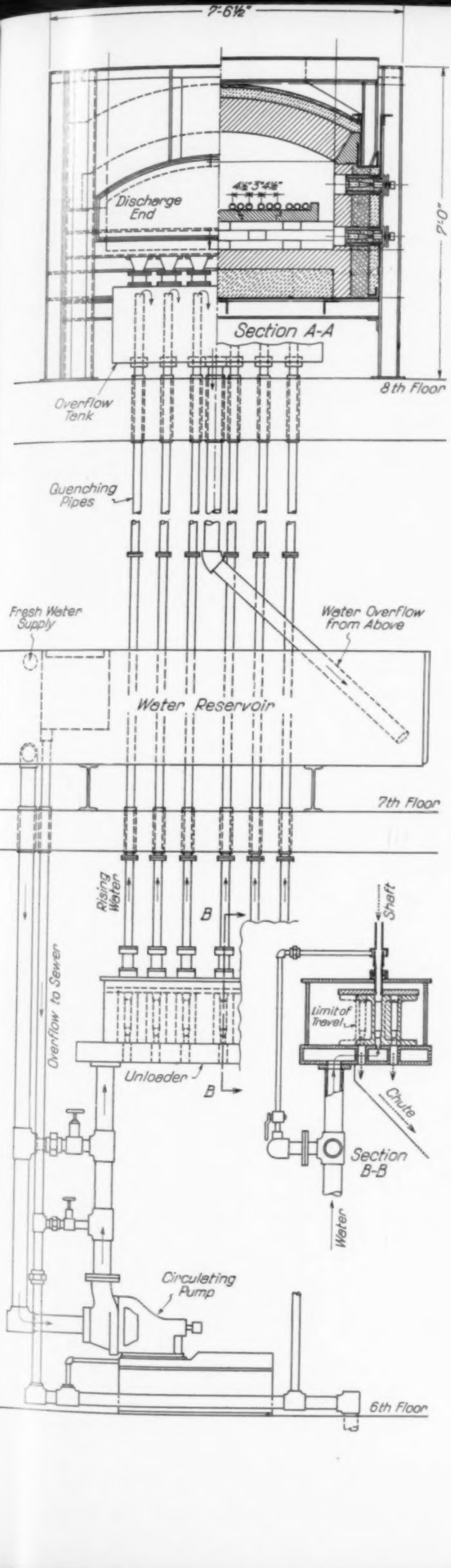
Reaching the end, the hot shaft slides around a curved discharge chute into the top of a vertical water pipe, extending downward 18 ft. through two stories in the building. Here it encounters a rising column of water at about 65° F. and is

at about 180° F. by the time it is discharged.

Three adjacent furnace tubes discharge into one vertical quenching tube, and the pusher is arranged so that the shafts follow each other at equal time intervals. As each one drops out of the furnace, it trips a lever and this actuates an unloading device at the bottom of the tube, so that as the hot shaft enters, the quenched one is discharged without losing any water from the circulating system. This device consists of a metal block as high as the longest shaft, and bored with two holes. As shown in the sketch, one hole registers under the vertical pipe above, and the other hole registers over one of two holes in the smooth bottom plate of the water-tight casing. Thus a cold shaft drops into the hole in the brass block, and when the next shaft trips the actuating mechanism the block moves quickly sideways until the other hole registers under the quenching pipe to receive the downcoming shaft, and the quenched shaft drops out the corresponding hole in the bottom of the casing. When the next shaft comes along, the motion of the block reverses, so the cold shafts drop out alternately through holes at right and left.

The shafts retain enough heat to dry them, and they are then placed singly on hangers on an endless chain conveyor and carried through a salt bath for a stress-relieving draw at 400° F. This tempering operation it needed only as insurance against slight variations in this automatic heat treating unit. If the steel, the atmosphere, the time-temperature relations on heating, the quenching rate were all *exactly* reproduced, shaft after shaft, conditions could be adjusted so that the quenched article would be just right. But any slight variation in the above major factors will cause the product to vary; therefore, the low draw is installed as a precaution.

At the present time, we have two furnaces working on this plan, an electric furnace made by Electric Furnace Co. with a water tank quench for short shafts, and a gas fired furnace made by Surface Combustion Corp. with the long vertical quenching pipes described above for shafts five inches long and longer. The principal advantage of the gas furnace is that small leakage of hydrocarbon gas from the tubes or end seals into the heating chamber causes no trouble, whereas there

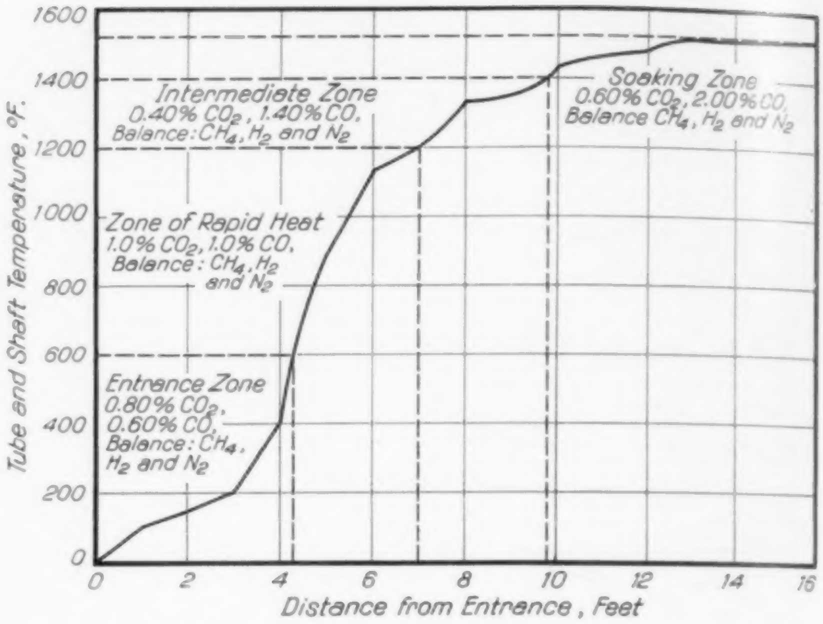


General Arrangement of Unloading Device, for Dropping Quenched Shaft Out of End of Pipe Without Losing Water Pressure, Is Shown at Left. Quenched shaft drops into hole in block, and thence through hole in tank bottom when block moves to one side to register another hole under quench pipe

is a tendency for the raw gas to form soot in the electric furnace on the resistors.

Alloy tubes have given 18 months' continuous service. While their temperature is only 1550° F. as a maximum, they are under considerable thermal stress due to the travel of cold metal through them. Still their life bids fair to equal the brick lining of the heating chamber.

Results can perhaps best be appraised by figures from inspection tests. About 15% of production is tested for hardness and straightness — the former test being the most indicative, for it has been found that any serious interruption in the steady flow of work, any hang-up of work in the heating or cooling, will cause sufficient variation in hardness to pull the shaft out of line. This relationship is shown in the table from an inspector's notes. Shafts 1, 2 and 5 are good shafts, while 3, 4 and 6 are low in hardness and also warped in excess of limits. As soon as any soft shafts turn up, an investigation is immediately made and the cause removed.



Graph Showing Changes in Temperature and Analysis of Gas in a Long Tube Filled With S.A.E. 1040 Shafts. Cold mixture of 1 part air and 1 part natural gas introduced at entrance with work

Relation of Hardness and Straightness

No.	Rockwell Hardness [C-Scale] at A	B	C	D	Straightness [Out of Line] By Indicator
1	58	59	59	60	0.006 in.
2	57	58	58	59	0.005 in.
3	54	50	51	60	0.015 in.
4	52	51	53	61	0.020 in.
5	59	58	59	59	0.004 in.
6	48	50	45	49	0.030 in.

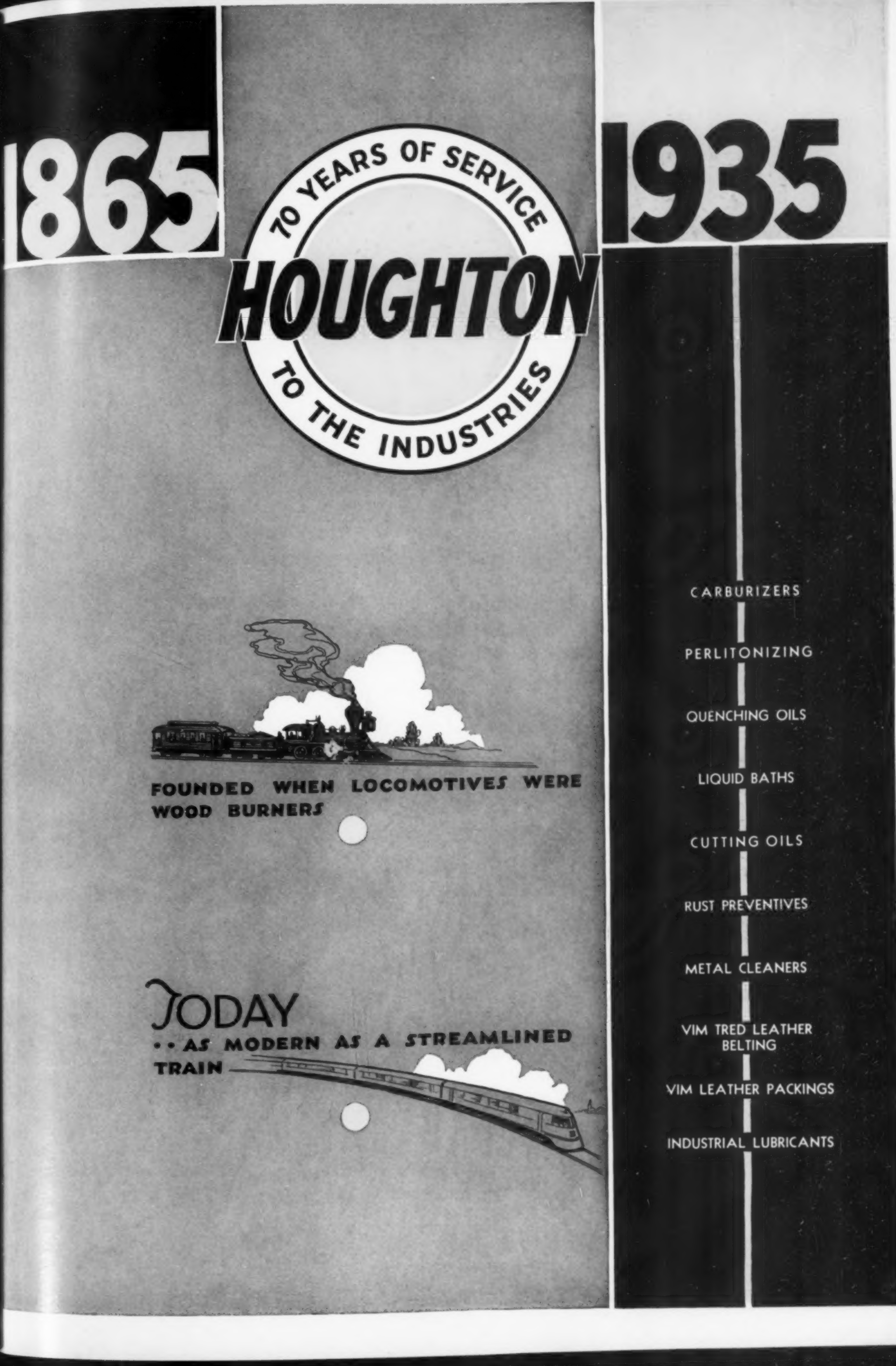
Occasional tests are made to destruction. One loads the hardened shaft centrally as a beam and notes the breaking load. This is then related to the shear strength of the shaft. The penetration and uniform depth of hardening can also be measured on such fractured surfaces. Relationship of cross breaking load and method of hardening is clearly shown in the tabulation at right of 12 shafts for Oldsmobile shock absorbers. All were loaded centrally, and rested on knife edges 4 in. apart. The shafts hardened in the old pusher type of furnace (open-hearth) carried a load of about 11,000 lb. at fracture; quenched vertically from cyanide baths they carried a load of more than 15,000 lb.; from the new process tube furnace they now carry at least 20,000 lb.

A complete assembly, selected occasionally at random, is also set up in a torsion machine and twisted apart and the result studied. The same Oldsmobile shaft, tested in this way, will give the following results in torsional shear: 16,560 in-lb.; 16,480; 16,465; 16,520; average 16,500 in-lb. Another fixture is available wherein an alloy steel sleeve with internal teeth is slipped over the ribbed portions of the 1040 shaft, and twisted until the latter is stripped.

We feel, as a result of our work on this shaft, that the general problem of hardening carbon steel parts from controlled atmospheres is measurably nearer solution. It is further our belief that the method indicated of introducing gas-air mixtures *with* the work and causing it to progress against rising temperature, will avoid many reported troubles in handling gas atmospheres.

Method of Hardening Affects Strength

Central Load to Fracture in Bending		
Pusher Type Furnace	Cyanide	New Process Tube Furnace
11,209 lb.	15,450 lb.	21,310 lb.
10,950	15,545	20,180
11,105	15,190	20,175
11,309	15,346	21,460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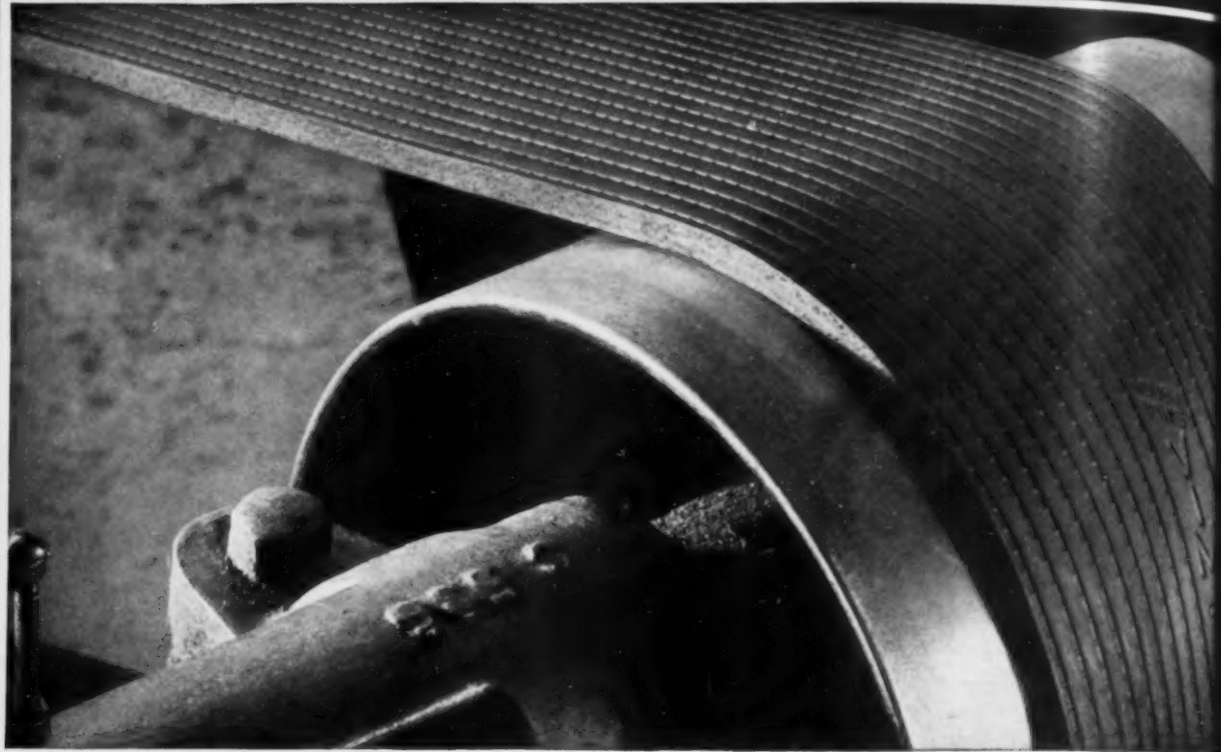

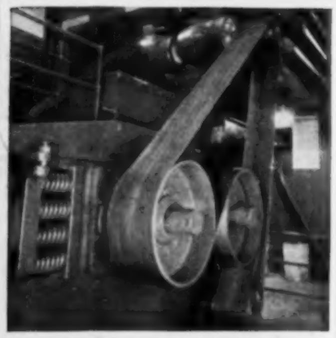

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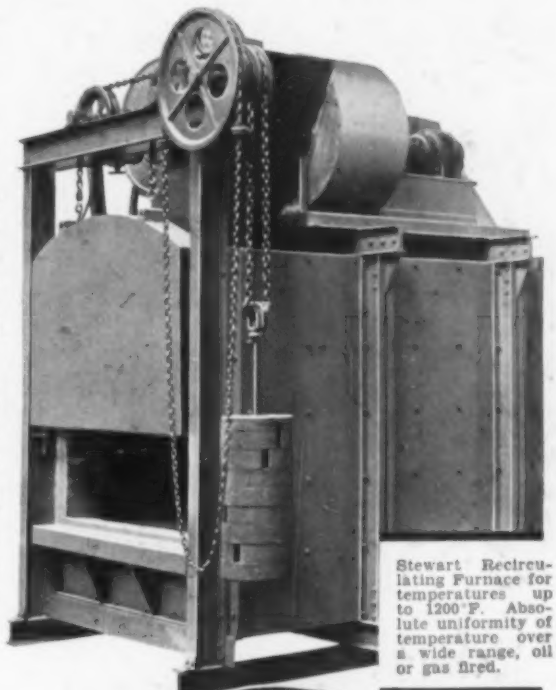

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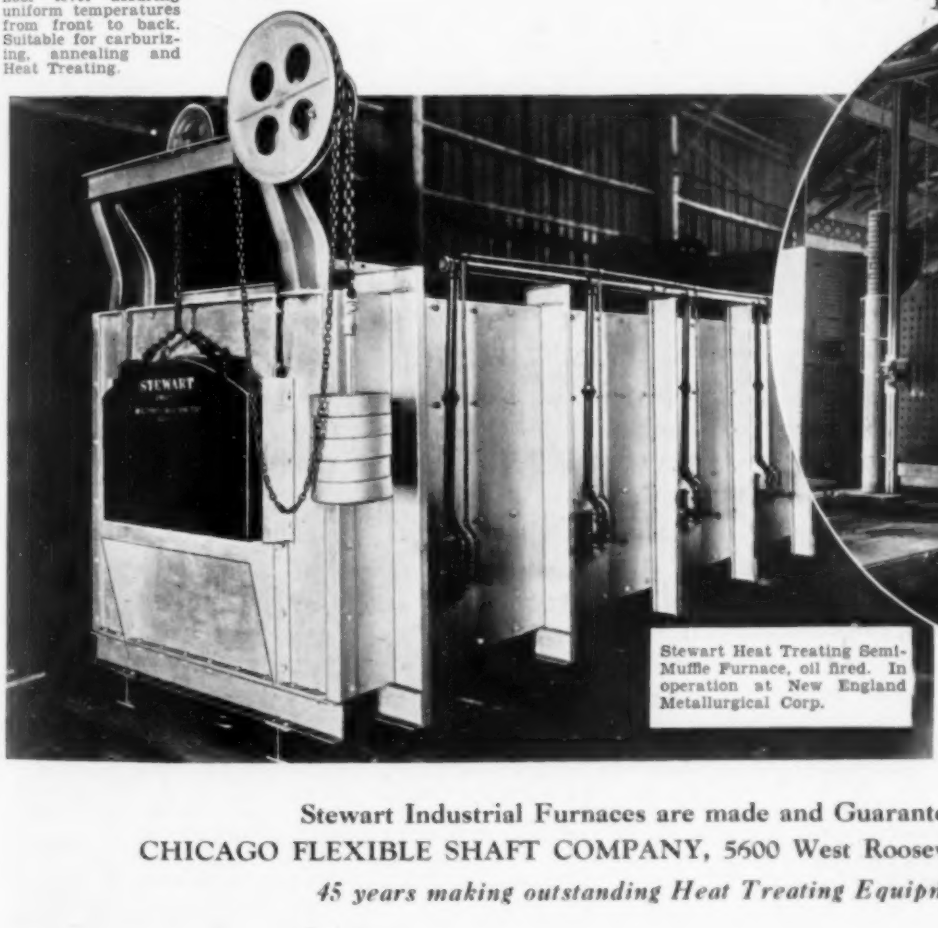
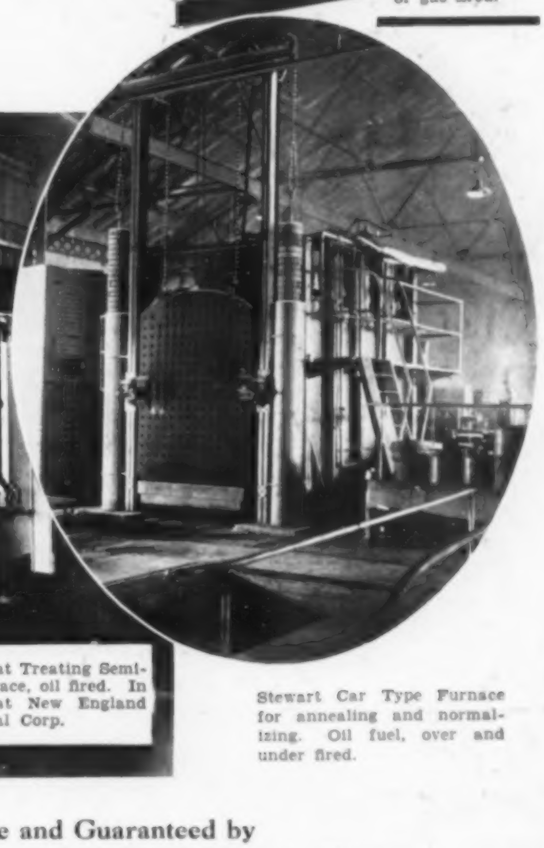


Stewart Heat Treating Semi-Muffle Furnace, oil fired. In operation at New England Metallurgical Corp.



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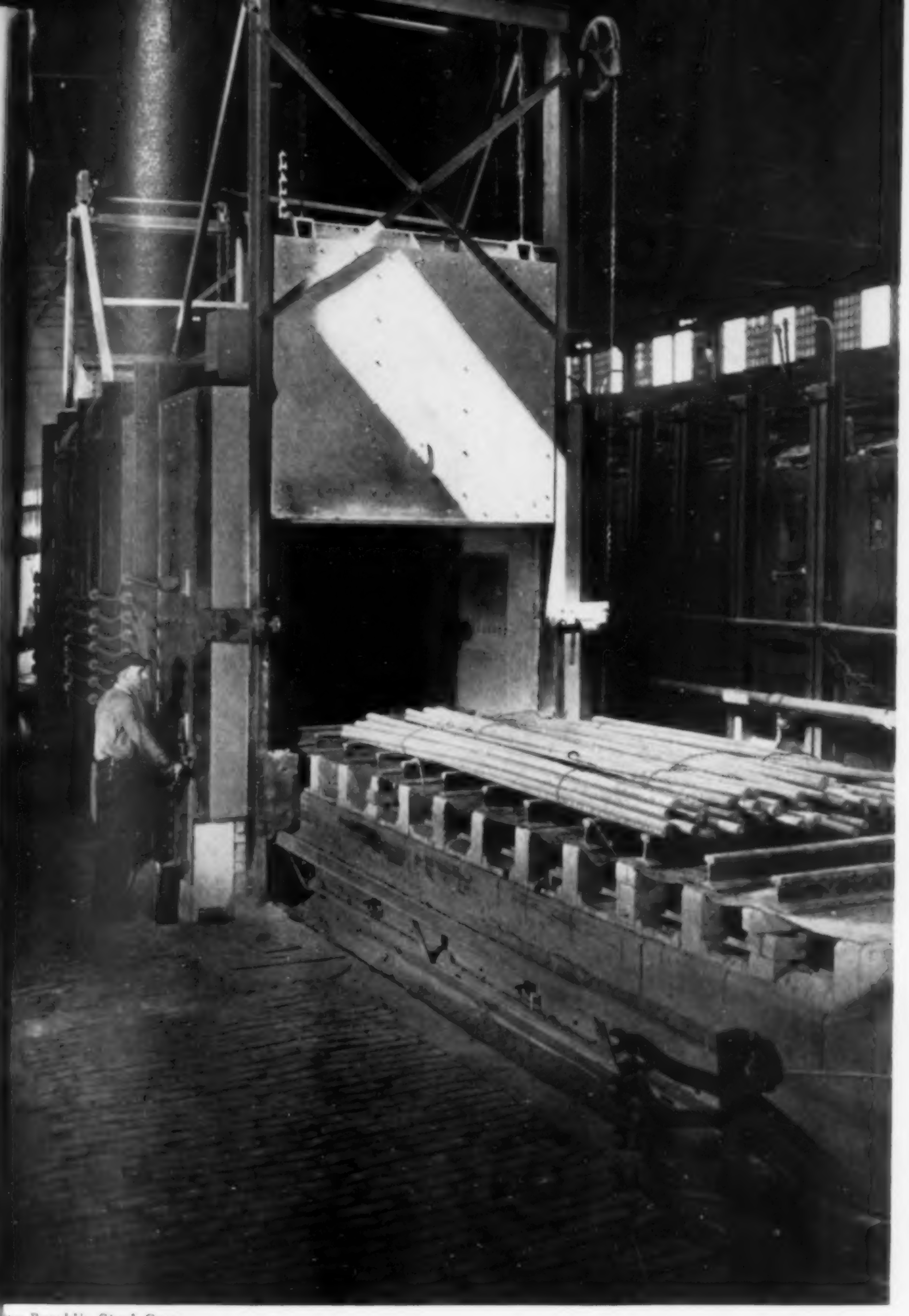

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FURNACES AND REFRACTORIES

In the Following Pages Will Be Found (In Addition to News From Manufacturers)

.... A Summary of Recent Work on Best Methods for Burning Gas

.... Specialized Refractories Made in Electric Furnaces for Severest Duty

.... Notes on Proper Operation of Heating Furnaces for Best Economy

SOME NEW DATA ON THE FUNDAMENTALS OF GAS COMBUSTION

ALTHOUGH KNOWLEDGE OF THE fundamentals of combustion of most elementary and simple gases has been well established, the application of these known data to existing problems of complex gas mixtures has been extremely difficult and in some cases impossible. With the increasing use of gas and the ever growing requirements for higher efficiencies and greater economies, it is essential to utilize all the available knowledge on the manner of gas combustion. To meet these demands for increased data, so that better gas furnaces can be constructed and operated at better efficiency, the Committee on Industrial Gas Research of the American Gas Association has been sponsoring, for the past five years, a series of investigations at the Association's testing laboratory to determine many of the yet unknown factors.

During this time much information has been secured and published in the form of several bulletins. Some of the most salient points of these studies will be given in this article, and in order to appreciate fully the significance of these new data it will be well to review briefly some of the previously known facts.

The combustible constituents of our city gases are usually hydrogen, carbon monoxide, methane, ethane, ethylene, benzene, butane, and propane. Accompanying these combustibles are small quantities of carbon dioxide, nitrogen, oxygen, and water vapor. Seldom do *all* of these constituents exist in any one city gas; a combination of *some* of them appears in every city gas, whether it is natural gas, manufactured gas, or mixtures of these. Therefore, to understand fully what goes on when gas burns, it is quite natural to look to the burning of these constituent gases for an explanation. While this preliminary procedure lends some assistance, the final answer was obtained only after the performance of considerable research work.

Although the quantity and composition of the flue products resulting from the complete combustion of a known quantity of air and gas can be ascertained from the chemical reactions of the individual constituents, the manner in which these reactions occur is not so well established. For example, we know that the products of complete combustion are carbon dioxide and water vapor, but we cannot say by just what steps these were formed from the constituent gases. Furthermore, we are not able to state exactly the procedure of the action at the present time, although we have considerable evidence to support various theories.

The old idea that a hydrocarbon gas, as encountered in city gases, breaks down on ignition into carbon and hydrogen and burns as such, has been replaced with a fairly well established hydroxylation theory. (For a complete discussion of this theory see "Flame and Combustion in Industrial Gases" by Bone and Townsend, published by Longmans, Green and Co.) This theory states that the hydrocarbon gas is progressively oxidized through several stages to carbon dioxide and water vapor — assuming that the combustion process is not interfered with and that sufficient oxygen is present to permit the action to go on to completion. It is interesting to note that if this action is stopped before

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it is completed, aldehydes are formed of which the familiar formaldehyde is very prominent. This will account, generally, for the peculiar odor noticed in the products of incomplete combustion. Likewise, it is a general truth that whenever you have an aldehyde present, carbon monoxide will also be present as a product of the incompleted oxidation process.

Although a great deal more could be said about some of the new basic theories governing the burning of these elementary gases, application of these data to practical problems of design is still very difficult. Therefore, one of the first problems investigated at our testing laboratory was the determination of what occurs when a city gas is burned in high temperature industrial installations, and what design limitations should be adhered to if economical and efficient operation is to be obtained.

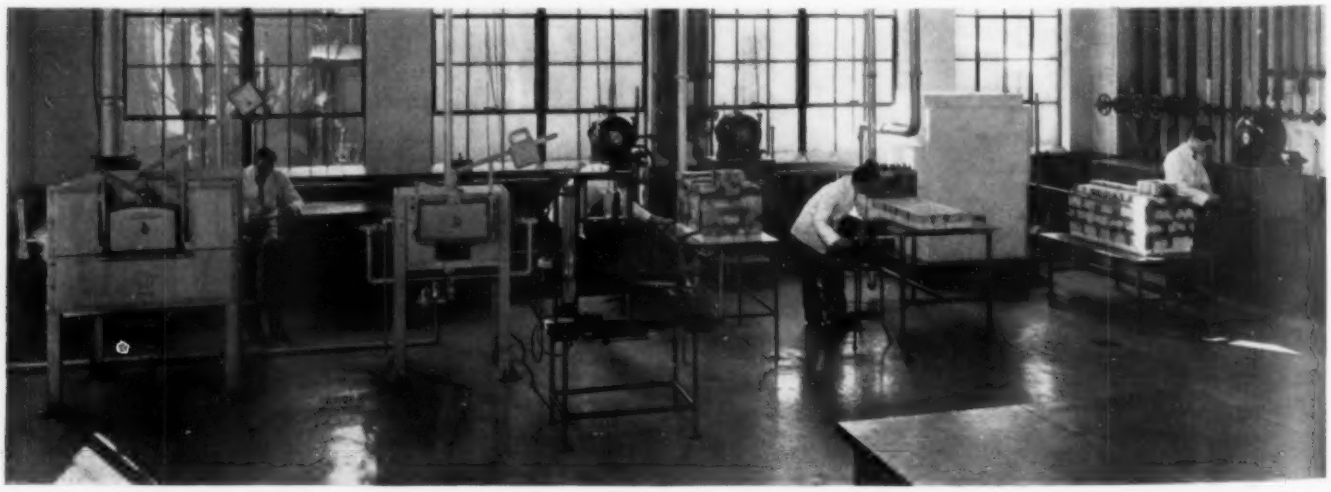
Types of Flames

The design and application of the atmospheric burner which employs the Bunsen principle is fairly well known; however, the various "zones" are present only when part of the air required for complete combustion (called "primary air") is introduced into the gas stream prior to combustion. If none of the air, or all of the air required for combustion is mixed with the gas before burning, entirely different conditions will exist.

These three distinct conditions of burning are schematically shown in the photo opposite. The most familiar one, the Bunsen flame, is shown in the center. The unburned air and gas exist in zone (5). Actual burning of the primary air and gas occurs on the thin surface (6) of the inner partly luminous cone. Since only a portion of the air required for complete combustion is supplied as primary air, the unburned constituents are then burned in zone (7) as oxygen is obtained from the surroundings by infiltration. The products of complete combustion are sometimes faintly visible in a zone outside of the reaction area.

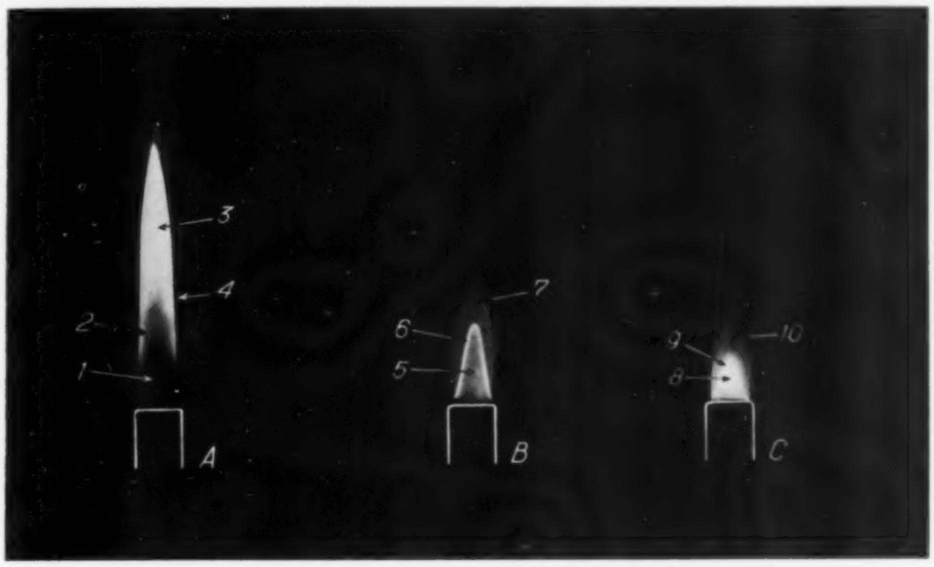
If, on the other hand, none of the required air is mixed with the gas prior to its passage through the burner, the familiar luminous or yellow flame is obtained as photographed at A. In this case, zone (1) is composed only of gas. Oxygen is obtained from the surrounding air which filters into the flame and combustion starts on the surface (2) of the inner cone. At the base of the flame sufficient oxygen is generally present to completely burn the gas in a thin sheath (zone 4, below). However, as only a small amount of air is available in the upper portion of the flame, partial combustion results, and the remaining hydrocarbons are decomposed producing a luminous region represented by zone (3). As additional air is obtained the unburned constituents are then completely burned in the outer zone (4).

The combustion principle employed for a large number of industrial purposes differs still further from these two cases just cited. In such cases *all* the air required to obtain complete combustion is mixed with the gas prior to ignition. A flame depicting this condition is shown at the right. Here the mixture of gas and all the required air is shown as zone (8). From general appearances it is rather difficult to tell the difference between flames with partial air and complete premixed air. The major difference lies on the surface of the inner cone. In this latter case



Battery of Equipment for Studying Fundamentals of Gas Combustion

the combustion of the gas is completed on the surface of the inner cone or zone (9). Instead of having a reaction zone around this cone, as in the Bunsen flame, a mantle (zone 10) of incandescent products of combustion exists. After these gases have cooled sufficiently so that they 10) the temperature is reduced so that the dissociated action reverses to a certain extent; some of the carbon monoxide recombines with oxygen to form carbon dioxide, and hydrogen recombines with oxygen to form water vapor. The luminosity of the gases in this zone may be par-



Three Varieties of Gas Flames

A. All gas	B. Gas plus part of air required	C. Gas plus all of air required
1. Unburned gas	5. Unburned mixture of air and gas	8. Unburned mixture of air and gas
2. Initial combustion surface	6. Primary air and gas combustion zone	9. Zone of complete combustion
3. Luminous zone of partial combustion	7. Zone where combustion is completed	10. Glowing products of combustion — hot flue gases
4. Sheath where combustion finishes		

are no longer visible, they have passed outside zone (10).

Dissociation and its Suppression

In order to describe fully the combustion of industrial gas, mention will have to be made of two other rather complex actions, that of the dissociation of carbon dioxide into carbon monoxide and oxygen, and the dissociation of water vapor into hydrogen and oxygen. If the temperature of the gas is sufficiently high, these actions will occur since both carbon dioxide and water vapor are present after combustion. It is doubtful if the flame temperature obtained by either the yellow or the Bunsen flame is high enough to cause dissociation, but it is in the case of the third flame. This action probably happens on or very near the surface of the inner cone where the temperature is the highest. As these dissociated products pass into the cooler region (zone tially caused by this burning of carbon monoxide and hydrogen.

In a large number of industrial installations, it is not desirable to have any gases of a reducing nature present. If the dissociation of carbon dioxide and water vapor is allowed to occur at the flame temperature, some of the resulting carbon monoxide and hydrogen as well as free oxygen will exist in the flue gases even at low temperatures. In other words, the reversal of the dissociation action approaches completion but never actually reaches it. Therefore, if the undesirable effects of these products of dissociation are to be avoided, it will be necessary to repress dissociation. This can actually be done by several methods.

If a sufficient quantity of air in excess of that required to burn the gas completely is mixed with the gas prior to combustion, the dissociation action can be completely repressed and no products of dissociation will be formed in the flue

products. The upper graph shows the quantity of excess air, expressed in per cent of excess oxygen as determined in a flue gas analysis, required at any given flue gas temperature to repress the quantity of carbon monoxide and hydrogen formed to 0.05%. This residue value was selected as representing a negligible amount and is about the minimum amount that could be determined accurately. The relationship between excess oxygen and excess air in the flue products for both natural and coke oven gas is shown in the second diagram on page 25.

Photo by J. P. Mudd for The Midvale Co.

In installations such as pot furnaces, the flue products discharge directly from the flame onto or alongside a metallic surface. The gas temperature at this point is considerably higher than later when it is discharged out the flue. Therefore, if all the carbon monoxide, hydrogen and active nascent oxygen, formed as a result of dissociation, are to be eliminated so as to prolong the life of the pot, it will be necessary to admit excess oxygen (air) corresponding to this high temperature as determined from the first curve. Likewise, in the case of overfiring, where some of the flue products may be circulated around the work before the gases have cooled to the furnace temperature, the amount of excess oxygen necessary to eliminate all the reducing products should be governed by the temperature of the gases at the outlet of these top burners, instead of at the furnace temperature.

The quantity of products formed from dissociation may also be reduced by preheating the air for combustion and by operating the furnace under pressure. However, no quantitative relationship for these two factors is available at the present time.

Limits on the quantity of gas that can be completely burned can be established from what has just been said about the manner in which gas burns. For example, if all the air required for combustion is mixed with the gas, there appears to be no need for a combustion space larger than that which is necessary to house the flame. If enough excess air is admitted to the mixture to repress the dissociation of carbon dioxide and water vapor, the combustion chamber would have to encase only the inner cone. Of course, this enclosure should not touch the flame so as to interfere with the combustion action. During our experimental work, gas was completely burned at the rate of 9,000,000 B.t.u. per hr. per cu.ft. of combustion space with no indication that greater quantities could not be completely burned. This is far in excess of that encountered in any of the industrial furnaces in use today.

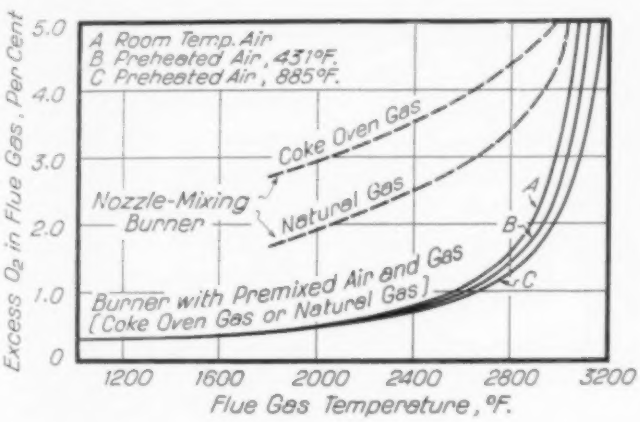
Quite naturally, the question arose as to the effect of the temperature of the combustion chamber wall on the quantity of gas that can be completely burned, especially when consuming such large quantities of gas per cubic foot of combustion space. To obtain as low a wall temperature as possible, a combustion chamber was constructed with water-walls. Unlike a boiler combustion chamber which this test furnace simulated, the outlet temperature of the water from this test furnace was not allowed to rise more than about 10° F. above room temperature. This wall temperature had no effect on the amount of gas that could be completely burned, a finding in direct accord with the theory of gas combustion as previously outlined. In other words, as long as the combustion chamber walls do not contact the inner cone of the flame and thus interfere with the combustion reaction, the wall temperature could have no direct effect on the amount of gas that could be burned when premixing all the air and gas.

In addition to the saving resulting from the utilization of preheated air (such as the recovery of waste heat to preheat the air), larger quantities of gas can be burned per unit of combustion space than when burning room temperature air and gas. This offers a method of increasing the capacity of a given combustion chamber without altering its general construction. If a premixing system is employed it should be re-

membered, however, that air temperatures in excess of 1000° F. may cause pre-ignition of the air-gas mixture at the point of mixing. Likewise, the use of preheated air increases the ignition velocity (rate of burning) of the mixture and if relative high degrees of preheat are utilized, it may be necessary to reduce the size of the burner ports to eliminate flash-backs, liable to occur at low turn-down rates.

New Features of Furnace Design

Having briefly discussed some of the fundamental findings of how gas burns, these data will now be applied to some actual problems met in everyday furnace practice.



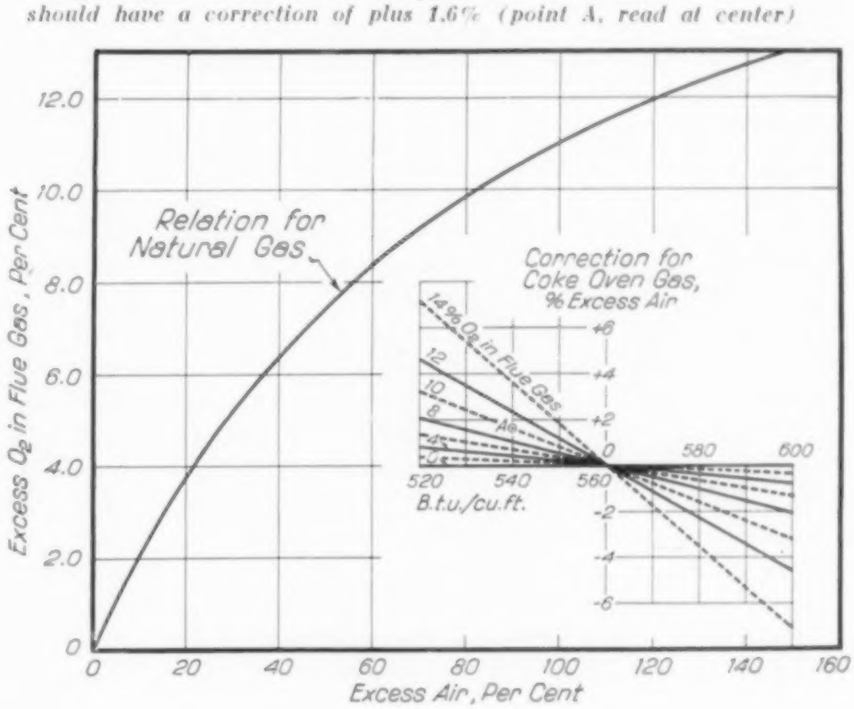
Amount of Excess Oxygen Necessary in Flue Gas in Order That There May Be No Dissociation of Products of Combustion. Premixed air and gas is much more efficiently burned at the lower temperatures

It is customary to design industrial furnaces with relatively large combustion chambers. Although this space doubtless has definite value, it cannot be rightfully called a combustion chamber, but rather should be termed a "heat exchanger." The amount of space actually required to burn the gas completely is usually a very small percentage of that provided. In view of this fact, the design of a furnace should consist of a combustion chamber (and, if necessary, a "heat exchanger") and the work chamber, together with means of handling fuel, flue gas and work.

Fortunately, very high flame temperatures can be obtained with gas flames. In most cases, however, these high temperatures are not desirable for the work in hand and it is necessary to cool the resultant gases before they are discharged into the work chamber. This can be done in one of several ways. In direct firing heat is generally imparted to the walls of the so-called combustion chamber and a large portion of this is transferred through the walls to the outside of the furnace, thus wasting a large amount of it. Several other means were determined for reducing the temperature with a corresponding saving in the amount of gas burned. Essentially, they consist of changing the original excess heat at the high temperature to radiant energy and then utilizing that energy to heat the work, in addition to employing the usual convected methods.

A direct fired furnace should be constructed so that the combustion chamber is directly adjacent to the work chamber, that is, the work chamber wall should serve as part of the combustion chamber wall. In this manner, instead of dissipating the heat absorbed in the combustion chamber walls to the outside atmosphere, it can be radiated to the work. (Likewise, the burners should be selected so as to convert the maximum amount of the liberated heat into radiant energy.) By constructing the combustion chamber, for example, in a vertical position, one wall of which would be next to the heating chamber and the wall adjacent to the outside fully insulated, this

Curves for Determining Excess Air From the Oxygen Analysis of the Flue Gas. The main curve is correct for 1100 to 1180-B.t.u. natural gas. If, for instance, 540-B.t.u. coke oven gas is burned and the flue gases contain 10% oxygen, the indicated excess air should have a correction of plus 1.6% (point A, read at center)



chamber could be made sufficiently long to permit the temperature of the flue gases to be lowered to the desired level before entering the work chamber. Then the work would be heated by radiant heat as well as convection. Exit flue openings could be placed in or on a level with the hearth, and the gases made to pass under it.

Selection of burners generally involves the type and number to be employed. Standard burners are usually chosen and no more installed than needed to obtain good heat distribution. Greater consideration should be given this question, for burners have a great deal of influence on the furnace performance. However, the most important requirements of a burner must be sought, since it is almost impossible to obtain a perfect one. To illustrate this, several important design details will be considered.

In order to obtain the best heat distribution, the maximum transfer of heat from the flame to the combustion chamber wall, and the maximum input per unit of combustion space, the *maximum* number of burners possible should be employed — just contrary to usual practice. Offsetting these desirable factors is the increased cost as well as the increased noise occasioned by using a large number of small burners. The noise can be appreciably reduced by employing streamlined burners. However, a turbulent flame affords greater heat transmission and permits complete combustion of larger quantities of gas per cubic foot of combustion space.

More and more is exact control of the atmosphere surrounding the work being demanded. In direct fired furnaces employing completely premixed air and gas in which the burners are tightly sealed in the furnace wall, the complete absence of any carbon monoxide and hydrogen can be insured by proportioning the amount of excess air necessary to secure this condition as noted in the curves herewith. On the other hand, it is possible to obtain a reducing condition of almost any degree in the furnace by decreasing the quality of air to the burners.

Industrial furnaces are operated for the purpose of supplying heat to some type of material. This heat may be supplied in any one of a number of ways, each of which will possess certain advantages. These various methods generally require specific burners and furnace design. All of the previous discussion has pertained to burners which required the mixing of all the air for combustion with the gas prior to its admission to the burner. This particular type is typical of the majority of industrial installations.

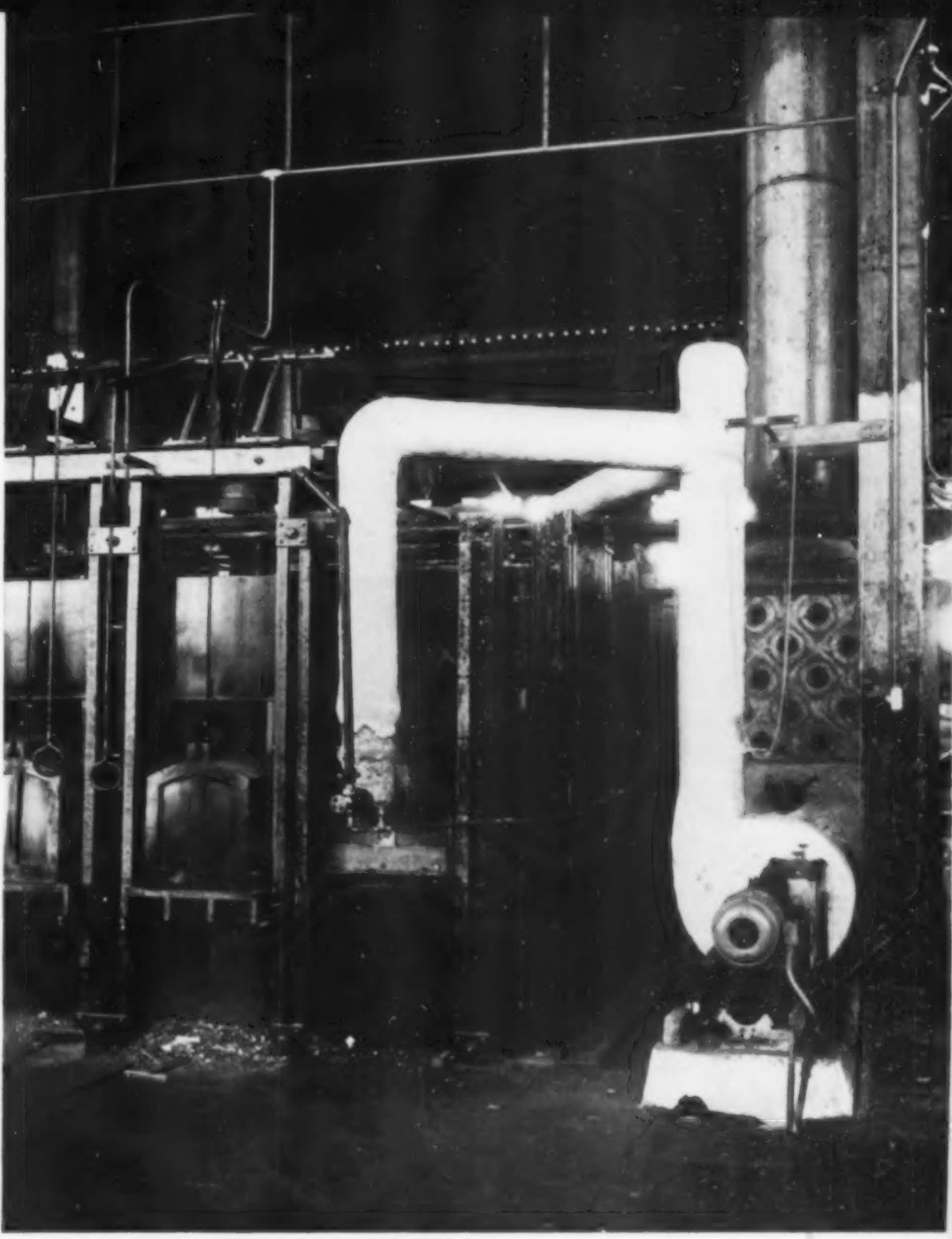
There is, however, another type of burner and combustion that is meeting increasing favor due to its particular characteristics. In this case, the air and gas are separately conducted to the combustion chamber and then discharged. The mixing of these two is performed after they leave the burners. Inasmuch as there are so many variations in design of this particular burner, no attempt will be made to give specific design data. Some very decided trends, however, have been established from tests on one particular type of nozzle-mixing burner, and the results secured should be considered when employing this type of burner in industrial installations.

The reader may refer to the description of the method of combustion of a diffusion flame (one in which none of the air required for combustion is premixed with the gas) as given in the first part of this paper. It applies to this type of nozzle-mixing burners. Instead of securing the air required for combustion from the surrounding atmosphere, however, it is supplied through separate ports in the burner. Since the air has to diffuse into the gas stream as it travels along, the combustion action will be slower than premixed air and gas. Likewise, the flame will necessarily be longer. Its length will be a function of the number and placement of the air and gas ports as well as the velocity of the air and gas streams. Considerably less gas can generally be burned per cubic foot of combustion space than with the premixed burner.

As seen from the dotted curves in the first figure, more excess air is required with this type of burner to obtain complete combustion (that is, to repress dissociation) than with one that premixes the gas and air. Because of its flexibility and its ability to control the length of flame, the nozzle-mixing burner is employed in furnaces where long luminous flames are desired. The relative merits of this type of heating, as compared to that discussed for burners employing totally premixed air and gas, are still debatable.

In general it may be said that far greater quantities of gas can be completely burned per cubic foot of combustion space than is now the general practice. Through proper furnace design and proper precautions in the selection of burner equipment, considerably more heat can be obtained from the burned gas by converting it into more useful forms. In this manner not only smaller furnaces can be constructed, thus reducing the initial cost, as well as the amount of heat lost to the atmosphere, but also the resultant furnace will be a more efficient heat exchanger.

SPECIALIZED ELECTRIC FURNACE REFRACTORIES



Recuperator for Waste Heat at Billet Heating Furnace

By J. A. King
The Carborundum Co.
Perth Amboy, N. J.

IN THE LAST TWO DECADES MANY IMprovements have been made in the methods of heat treating metal. It has been said that in that time heat treating has become a science rather than an art. Accurate pyrometers and automatic temperature controls have replaced the eye of the operator for controlling temperatures. Conveyor hearths fix the time element. Atmospheres are often rigidly controlled. Definite, rigid specifications covering every step of the heat treating operation have replaced the more or less secret individual formulas of the old-time heat treater.

But in no phase of this work has there been a more noticeable improvement than in the furnace, the heart of the process. It is a far cry from the open forge for hardening tools, used everywhere not so many years ago, to the controlled atmosphere electric or fuel fired furnace of today. Instead of being a pile of brick unsuccessfully attempting to hold in the heat, the modern insulated furnace is a fine precision instrument designed for the proper application and control of heat.

Underlying this refinement of furnaces has naturally been a correlated development in refractories. Gone are the days when a "hard burned" or a "soft burned" firebrick was the answer to any furnace problem. Today different refractories can be definitely selected for the various sections of the furnace where they will be the most economical. An excellent article in last October's Metal Progress described recent developments in so-called insulating refractories — porous brick of pure high alumina clay which not only resist the passage of heat but which can be used in a much higher temperature range than could the insulating brick formerly available.

The present article will supplement the one last year by giving a brief view of specialized electric furnace refractories — that is, refractories made from electric furnace products. As their unusual qualities are becoming recognized, their use is steadily broadening.

The special properties of the various types will be mentioned in detail below. Generally they are used in applications where temperatures are too severe for ordinary refractories, such as fireclay, silica, magnesite, or chrome brick, or where some other atmosphere or slagging condition is present that makes their use more economical. Electric furnace refractories are not intended to replace ordinary ones in all parts of a furnace — rather they are designed to give better service in certain portions.

Representative Properties of Commercial Refractories

Refractory	Relative Loss by Spalling		Inches Abraded at 2450°F.	Cross Breaking Strength		Mean Thermal Conductivity 1100 to 2450°F. B.t.u./ft.²/in./°F./hr.
	No. of Coolings	Per Cent Loss		70°F.	2450°F.	
Silicon carbide	100	nil	0.01	2103 psi.	900 psi.	108.2
Fused alumina		high	high			23.2
Grade A fireclay	40	4	0.11			9.0
Grade B fireclay	10	65	0.09			
Bauxite	10	43	0.04	1315	99	
No. 1 silica	4	100	high	608	145	12.2
Chrome	7	100	0.27	1392	22	
Magnesia	3	100	12.5	1388	136	25.8
Insulating brick						2.6

There are three classes of such products, arranged in order of their present importance: I, Silicon carbide refractories, SiC; II, aluminum oxide refractories, Al_2O_3; III, fused aluminum silicate refractories, $3\ Al_2O_3 \cdot 2\ SiO_2$.

These are produced in the form of standard bricks, tile, tubes, and special shapes. They are also essential constituents of the highest grades of refractory cements for laying and patching brick and for monolithic rammed linings.

Silicon Carbide Refractories

Silicon carbide is a manufactured product. A mixture of very pure silica sand, petroleum coke, sawdust and salt is packed around a graphite core in a trough-like electric furnace and raised to a temperature of about 4000° F. by means of a heavy electric current, passing between carbon electrodes at either end through the graphite core. At this temperature crystals of silicon carbide are formed. The sand provides the silicon, the coke the carbon, and the salt is added to take out any impurities (such as iron, which is distilled off as ferric chloride). The sawdust burns and makes the whole mass porous, permitting the escape of the voluminous gases produced by the reactions.

When it was determined that silicon carbide was stable up to its dissociation point (above 4000° F.), it was recognized immediately that it possessed unique refractory properties. Many years of development work by The Carborundum Co. were necessary, however, before the present type of silicon carbide refractory for heat treating and other high temperature furnace work was perfected. This grade of refractory contains no foreign bonding agent. Consequently there are no lower melting or inferior materials to weaken the structure at elevated temperatures. Several grades and types have been perfected, each suitable to specific applications.

In the manufacture of refractories the silicon carbide crystals are crushed to the desired size. The grain is bonded with a suitable temporary bond and pressed into shape. After thorough drying the shapes are fired to a temperature of 2675° F., at which temperature the permanent bond is developed.

As noted in the attached table, this refractory has a thermal conductivity about 12 times that of grade A fireclay brick. It is approximately eight times as strong as fireclay brick at 2450° F. and has about one-tenth the abrasion loss. Freedom from spalling is a remarkable inherent characteristic. It is because of this combination of properties that silicon carbide refractories give such long life and efficient, economical service in the proper sections of industrial furnaces.

Some examples of its use in typical heat treating furnaces might be of interest.

In a plant heat treating drive shafts and axles in box type furnaces with inside dimensions of 36x72 in., "Carbofrax" hearth and supports replaced fireclay. Because of its much higher strength, a 3-in. thick hearth replaced the 5-in. clay hearth, and the new supports eliminated spalling and sagging under load formerly experienced. Operation of the furnace with accurate

gas meters showed an immediate saving of approximately 30% in fuel while turning out the same amount of work. It was further definitely demonstrated that the quality of work was improved, due to the fact that it was being equally heated top and bottom. These improvements in operation were, of course, directly traceable to the high heat conductivity of the silicon carbide floor and more than warranted its additional first cost. An additional saving was obtained, however, in the much longer life. Where it had been necessary to replace fireclay floors and supports every six months, the special refractory gave three years' uninterrupted service.

At another place a silicon carbide floor replaced a fireclay floor in a box furnace 18x36 in. inside dimensions, heat treating forging dies for the manufacture of scissors and shears. An immediate improvement in operations was noted. Great care had to be taken when operating with a fireclay floor to avoid overheating and consequent warping of the uppermost or working face of the die, since most of the heat was absorbed at the sides and top from the gases coming up around the edge of the floor. Comparatively little heat came to the bottom of the die block through the fireclay floor with its low heat conductivity.

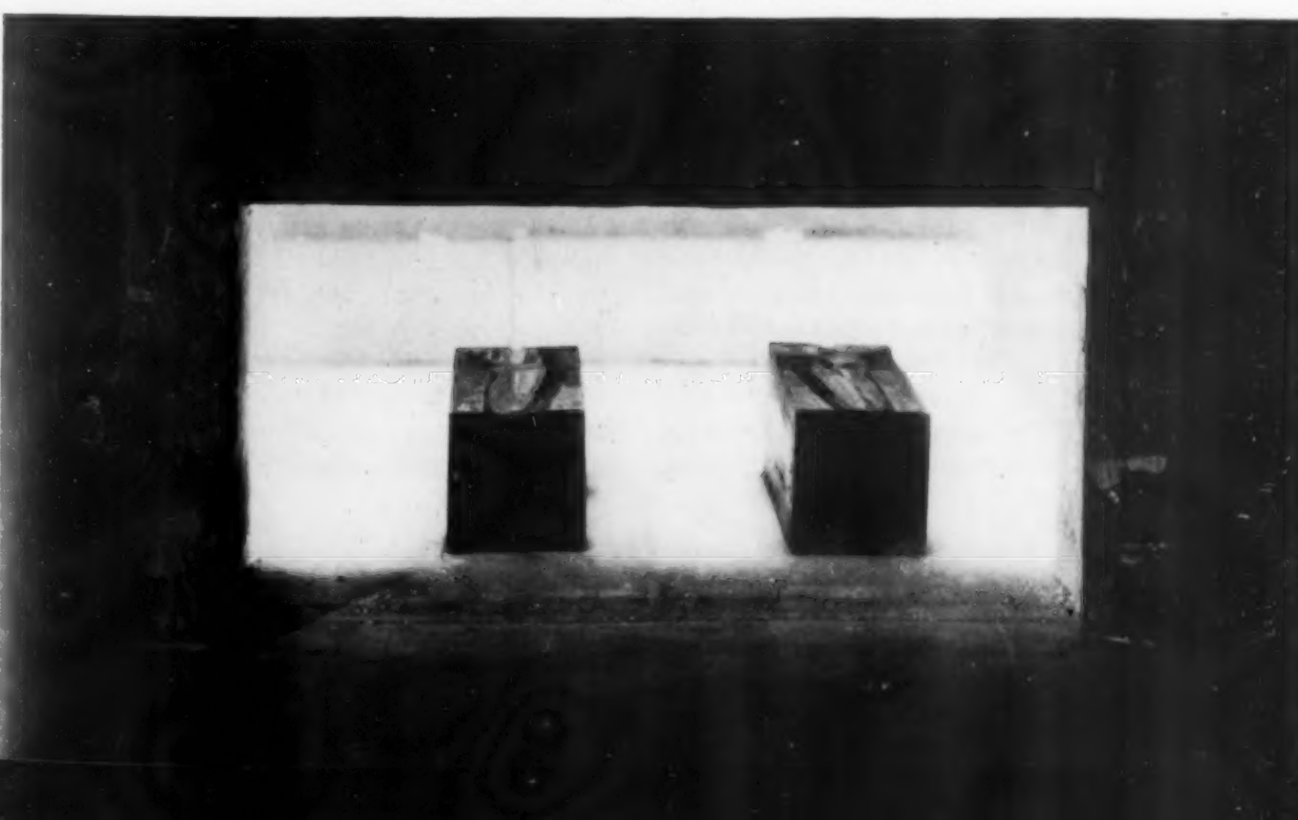
As can be seen from the photograph on this page, with the silicon carbide hearth sufficient heat was transmitted to the bottom of the die so that top and bottom were heated evenly. Furthermore, the fuel consumption was reduced by approximately 20% during operation over and above a saving in heating-up time. Where it had been necessary to light the furnaces 5 hr. before beginning work to get an evenly distributed temperature, it was possible to bring the furnace up to temperature with the heat evenly distributed in 1 hr. The new hearth lasted about four times as long as fireclay.

Applications of Special Refractories

Silicon carbide refractories have been used successfully in hardening, carburizing and annealing furnaces, high speed steel furnaces, stainless steel annealing furnaces, forging furnaces, roasting furnaces and zinc retorts. Aside from the metallurgical field, installations have been successful in boilers, porcelain enamel muffle furnaces, driers, air heaters, as kiln furniture for ceramic ware and in many other applications.

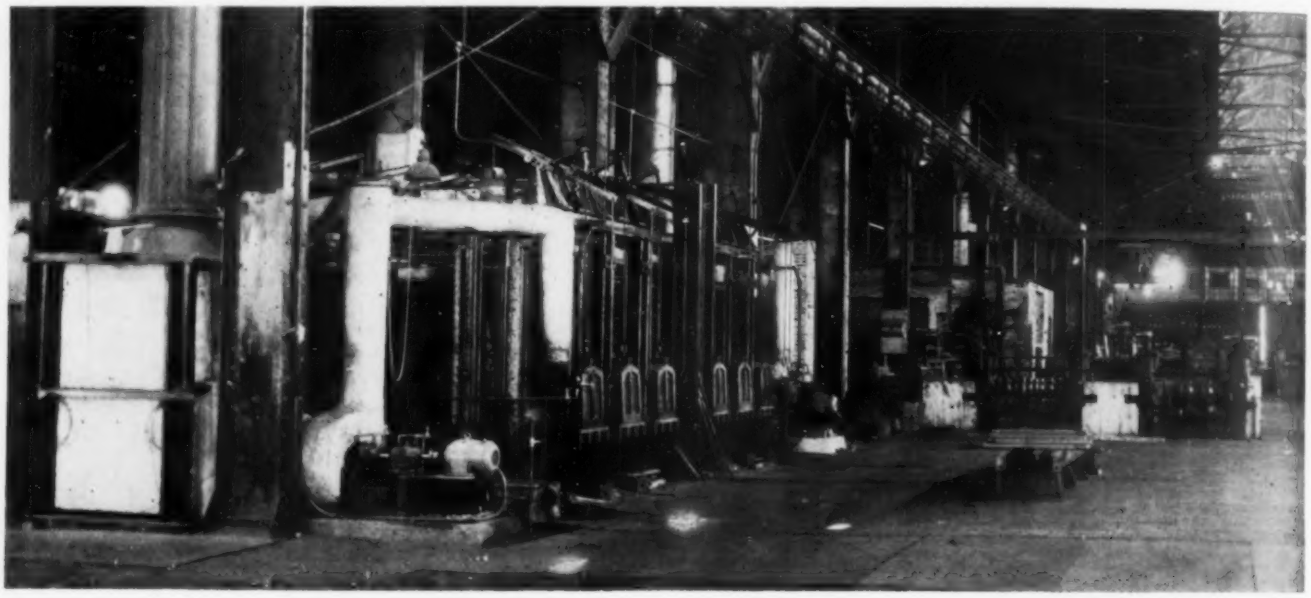
One development in the field of heating in controlled atmosphere that merits attention is the so-called "Carboradiant" chamber. One such application shown on the second following page has rectangular combustion chambers made of silicon carbide tile just under the spring lines of the flat arch. These are of relatively small cross-section and a length and height depending on the quantity and grade of fuel to be burned. The fuel is fired into the chamber with the correct amount of air; complete combustion is obtained because of the intimate mixing of the vaporized fuel and air in the restricted cross-section. The tiles forming the chamber quickly become incandescent, thus assisting in quick combustion of the fuel. Due to the high thermal conductivity of the silicon carbide a large percentage of the heat generated is transmitted through the tile and transferred to the work by radiation. Gases blow out through a series of graduated side ports, bathe the work and escape through flue openings in the hearth at center line of furnace and pass to a recuperator.

Underfired Die Furnace Equipped With Silicon Carbide Hearth Heats Dies Efficiently From All Directions



It is possible to control furnace atmospheres accurately by properly adjusting the air-fuel mixture admitted to the combustion chamber. Here it is completely burned and the gases then bathe the work to be heated. This avoids the stratification of gases which usually occurs in a direct-fired furnace with the result that the latter type always contains considerably more oxygen than can be accounted for by the amount of excess air admitted with the fuel.

This type of construction has been used in wire bakers, billet heating furnaces, carburizing malleable iron air furnaces, open-hearth furnaces, muffle enameling furnaces, forging furnaces, revolving pot glass furnaces and tunnel kilns. In this recuperator silicon carbide is employed in tube form. The waste gases are conducted around the outside of the tubes and the air to be heated passes through the inside. Fireclay rods or "core busters" are placed inside the tubes, thus forcing the air to contact the tube walls, breaking up any cold stream in the center and eliminating a dead air film on the inside wall surface.



Billet Heating Is Efficiently Done in Oil Fired Furnace, Flame Burning in Radiant Chambers at Each End, Flue Gases Passing Through Recuperators Before Reaching Stack. For close-up of recuperators and burners see view at head of article

furnaces and in many other types of metallurgical furnaces because the close control of furnace atmosphere reduces the amount of scaling, and the better heat distribution results in high quality work.

Another wide use in this category is for heat transfer elements in recuperators. Because of its high thermal conductivity a recuperator constructed with silicon carbide elements is much more efficient per unit of heating surface than is a fireclay recuperator. In addition, due to its refractoriness it will withstand excessive temperatures without softening or deforming. It will furthermore give very satisfactory service under corrosive gas and high temperature conditions which have a detrimental effect on metallic tubes or elements.

One type of recuperator is illustrated, which is being successfully operated on alloy billet heating furnaces, continuous reheating furnaces,

These tubes are accessible for cleaning and replacement. They can be removed from the unit and new tubes installed without dismantling the fireclay terminal walls. The outside of the tubes can be cleaned of dust or slag accumulation through appropriate clean-out doors.

Refractories of Fused Alumina

The second general type of specialized refractories is that made of fused alumina. This product is made of highly purified fused alumina and should not be confused with "high alumina" or diaspore brick. Fused alumina is made from bauxite (an aluminum ore in which the aluminum is largely present as hydrated oxides); some grades are chemically purified as is done prior to the manufacture of the metal aluminum, and then fused in an electric arc furnace. It is thus quite different from kiln-burned high alumina

brick, which is made from a hydrated alumina ore entangled with more or less clay, and after calcining and firing contains about 70% Al_2O_3.

In the manufacture of refractories from electric furnace alumina, the molten oxide is cooled, crushed, mixed with ceramic bonds, molded into shape, and fired in a kiln at elevated temperatures.

The fused alumina refractory has specialized uses which complement those of silicon carbide refractories. It has a very high dielectric strength and is, therefore, widely used in electric furnaces. It has a thermal conductivity about three times that of fireclay brick and may be used in furnace construction in the shape of muffles and retorts.

Silicon carbide is the base of many high temperature cements. These cements are used for laying up silicon carbide brick and shapes to insure a bond comparable with the refractory used. It is also used as a protective coating over brickwork of other sorts, including the new high temperature insulating brick.

Much of this type of cement is used for rammed linings in brass melting furnaces fired with either coal, coke, or oil. In a coal or coke fired furnace, relining is necessary not because the fireclay brick actually burns or melts out, but because clinkers attach themselves to the brickwork and fuse, and when these clinkers are broken out they carry away some brick with them. Soon the diameter of the combustion chamber becomes too large for its proper duty. A lining of silicon carbide cement lasts much longer than clay refractories because the coal or coke does not fuse to the lining. It is also capable of withstanding an impinging oil flame, which fuses a fireclay brick lining, particularly when driving the furnace hard enough to melt monel or high nickel alloys.

Interior of Hot Billet Furnace, Looking Toward Radiant Chamber at One End. Hot gases from oil flame discharge through graduated side ports into work chamber and are drawn off through vents in hearth at center of furnace

Some trouble was experienced with rammed linings of silicon carbide cement in the rocking type of electric furnaces when melting copper alloys with more than 3% of lead. A lead silicide was formed, supposedly by reaction with the lining, but it is questionable whether the molding sand clinging to remelted gates and sprues would not give the same result. However, this possible source of trouble has been overcome with fused alumina cements, and these are being used satisfactorily in this service, not only for new linings but also for patching and washing preburned linings in the smaller units. This same type of cement is a favorite for making rammed burner tunnels in gas fired furnaces.

Fused mullite linings are proving quite satisfactory for rocking electric furnaces of the "Detroit" type when melting ferrous metals, although there are instances where a silicon carbide cement, such as is used for rammed linings in nonferrous melting furnaces, has also proven quite satisfactory.

Brief mention should again be made of the high temperature insulating brick now available. This deserves careful consideration by furnace users, because it is possible through its use to increase the furnace efficiency greatly. Until recently most of the insulating bricks were made of diatomaceous earth; structurally they are weak and they cannot stand flame impingement or high temperature. The modern high temperature insulating brick is quite another type as it is made from kaolin, or some other equally refractory material and would class as a high quality firebrick were it not for its high porosity. It has fairly high crushing strength and little or no shrinkage at high temperatures.

If the fire face of such brick is coated with silicon carbide cement, it will withstand flame impingement very satisfactorily. These bricks are being used in furnace construction today in many cases to replace firebrick and thus greatly cut down the heat losses and increase the efficiency. It is curious to note that whereas silicon carbide refractories offer one extreme in conductivity and these insulating refractories the extreme in the other direction, when used in combination in the right places they greatly assist in adding efficiency to all types of furnaces.

NOTES ON HEATING FURNACE ECONOMY AND OPERATIONS

Pusher Type Furnace, Gas Fired, for Annealing Transmission Gear Forgings. Courtesy of Ford Motor Company

Portions of a Section Written for the 1936 Edition of National Metals Handbook

By M. H. Mawhinney
Salem Engineering Co.
Salem, Ohio

DESPITE THE FACT THAT ACCURATE information on the design and construction of heating furnaces has accumulated rapidly in the last 20 years, it still remains true that the design and construction of an efficient furnace — as of any other rugged and efficient machine — is best left in the hands of specialists. These are relatively few, so any general notes which can be jotted down here had best be confined to some of those items which can properly be used by an intelligent purchaser (who are many) in sifting the claims of salesmen and selecting and operating a proper heat treating machine.

Necessarily many remarks must be highly generalized, for a multiplicity of furnace designs are available even when only the varieties of fuels, the method of handling the work, and the nature of the work to be done are considered. The correct selection requires knowledge of the requirements to be met, and a practical understanding of the limitations of the various materials of construction at elevated temperatures.

However, the following rules should always be followed:

I. A furnace is a heat treating machine and the method of conveying the material must not compromise the heating characteristics of the furnace.

II. The advantages of simplicity in the design of conveyor hearths should not be overlooked in a desire to save labor.

III. Conveyors which will damage the material must first be eliminated. (Examples are the scratching of non-ferrous metals, damage to threaded parts, sagging and denting of tubular products.) Means for conveying which interfere with the circulation of heat must also be eliminated where precision of heat treatment is necessary. From the remaining available methods, a selection can be made by a careful study of the comparative operating costs, including maintenance and fixed charges on the investment.

Furnaces usually handle work either in batches or a continuous stream. Batch furnaces may have a stationary hearth (with solid or roller bottom), a car bottom or an elevator hearth; likewise the furnace itself may be movable from one bottom to another. Continuous furnaces may be of the tunnel type (either single stream or counterflow) with equipment for pushing or pulling the work through on pans, skids or in cars; the hearth may be a woven belt or a chain conveyor with moving fingers, or be of walking beams or a series of rollers. Rotary hearth or turret types of furnaces are continuous, as are also rotating retorts.

For estimating comparative operating costs of different designs, it is safe to assume that firebrick linings will last for two years at temperatures below 1900° F., and for one year above 2000° F. This does not apply to door jams, piers and bridgewalls, which will require additional patching. The life of metal parts when properly designed for stress and usual furnace conditions will be approximately as follows: Cast iron will last five years below 1400° F., one year at 1700° F., and five months at 1800° F. Sound nickel-chromium-iron alloy castings will last three years at 1700° F., 18 months at 1900° F., and 6 months at 2000° F.

Life of Furnace Parts

The life of a furnace at a given temperature depends upon the rate of heating, which may be expressed in pounds per square foot of hearth area per hour. The maximum allowable rate of heating steel parts which can be fairly closely packed is about 35 lb. per sq.ft. per hr. for underfired and overfired furnaces, 70 lb. for sidefired furnaces, and 100 lb. for direct fired furnaces. These are upper limits which should not be exceeded if long life of the furnace refractories is expected. The above rates are for heating mild steel, and may be about twice as great when heating brass, 2½ times as great for copper, and 0.7 times as great for alloy steel.

The above figures for allowable safe rate of heating vary according to temperature. At drawing temperatures of about 1000° F., the usual rate for steel is about 25 lb. per sq.ft. per hr., compared to the allowable rate of 35 lb. given above for heat treating at 1500 to 1600° F. By means of fans for air circulation, this rate may be increased to 35 lb. in electric furnaces. At heat treating temperatures of 1500 to 1600° F., air cir-

culation will not ordinarily increase the rate of heating sufficiently to be worth while, because the amount of heat transferred by convection is small in comparison with that by radiation and conduction.

Economy of Furnaces

The heat input to a heating furnace is distributed in various ways, depending upon the type of furnace. The efficiency of the furnace is that amount of useful heat going to the work in proportion to the total put into the furnace. The author's book on Practical Industrial Furnace Design may be consulted for detailed methods for figuring this heat balance.

The table below gives the average fuel economies (rather than the efficiencies) for typical heating furnaces of good design, properly operated. "Economy" means the B.t.u. of heat which must be liberated in fuel fired furnaces to heat one pound of material (or kw-hr. per ton of material in electric furnaces). The heat values given in the table are averages of good operation at efficient rates of production, and are for operation without heat saving devices.

To obtain the actual fuel consumption of a given furnace, divide the economy in B.t.u. by the net heating value of the fuel under consideration. (For this purpose the theoretical heating value of the fuel — or the gross chemical energy with products of combustion cooled to room temperature as given by computation or a calorimeter test — should be reduced by the amount of heat necessary to convert the water in the flue gases to vapor.)

Energy Liberated in Furnace to Heat Unit of Work

Operation	Average Temperature °F.	Fuel B.t.u. per Lb.	Electricity Kw-Hr. per Ton
Drawing: Batch type	1000	700	120
Chain conveyor	1000	500	110
Hardening or normalizing:	1500 to 1700	...	...
Batch type	....	1250	300
Rotary hearth	....	850	210
Pusher, direct	....	900	225
Pusher, pans	....	1400	340
Chain conveyor	....	1000	245
Car type	....	1200	290
Roller hearth; steel sheet	....	850	...
Box anneal, sheets	....	1300	...
Carburizing in boxes:	1650	....	...
Batch type	....	1500	400
Pusher, straight	....	1200	325
Pusher, counterflow	....	....	...
Recuperative	....	750	150
Enameling:			
Sanitary ware, 3 coats	1750	2150	...
Continuous, flat ware	1500 to 1650	....	...
Ground coat	....	2500	320
Finish coat	....	1750	220
Lead pots:	1500	1500	225
Heating for forming:	1900	....	...
Batch	....	1750	...
Continuous pusher	....	1600	...
Plate reheating	1800	1800	...
Forging:	2200	....	...
Batch	....	2800	500
Continuous, pusher	....	1400	...
Rotary hearth	....	1600	...
Wire patenting:	1850	1500	...
Heating for rolling:	2400	....	...
Batch, 4 to 6 doors	....	1800	...
Continuous pusher	....	900	...
Soaking pits for hot ingots:	2400	600	...
Copper billet heating:	1700	500	...
Annealing brass and copper:	1000 to 1200	...	...
Pan type batch furnace	....	400	...
Continuous, pans	....	350	110
Continuous, chain	....	350	110
Continuous, counterflow	....	160	50
Heat treating aluminum:			
Continuous, forging	880	...	140
Pit type; 21-hr. heating	960	...	265
Car type	975	...	200

Comparative Costs of Fuels

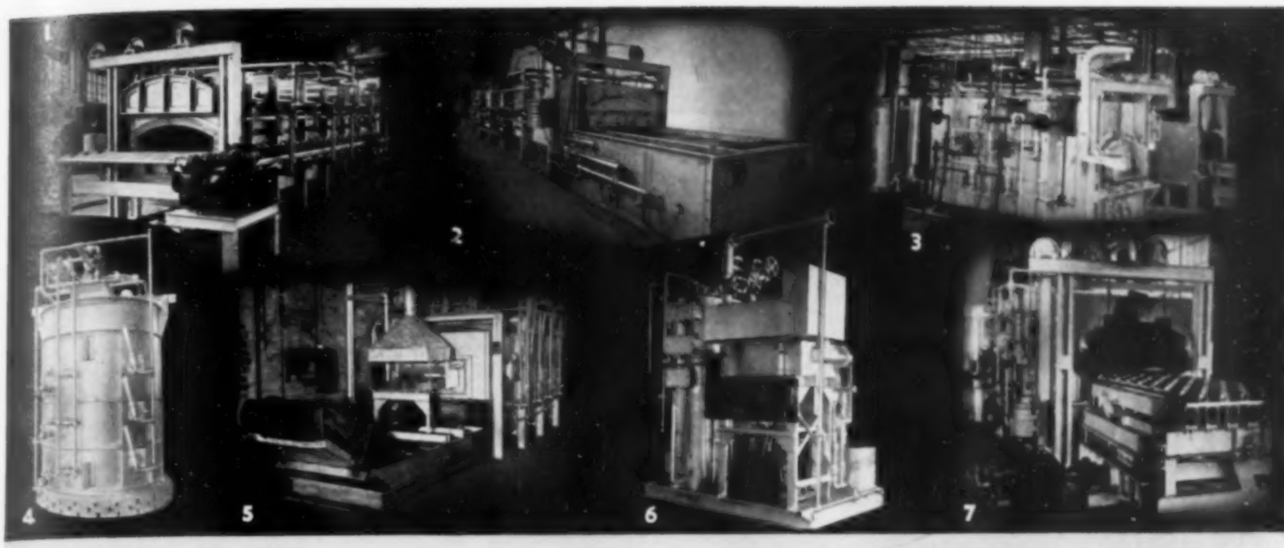
In comparing the over-all cost of operation of different kinds of furnaces, the major items for consideration are (1) charges on the investment, (2) labor, (3) maintenance and (4) fuel. The first three items depend largely upon the construction of the furnace and the type of conveyor or other mechanism involved for handling.

Much has been said and printed about item (4). A true comparison of fuel cost must include a consideration of the percentage of heat lost in the flue gases. For example, *all* of the heat liberated in an electric furnace at all temperatures goes to the material being heated, the furnace lining, or radiation through walls and openings. A fuel fired furnace involves an additional loss in the flue gases leaving the furnace.

The table on the opposite page gives the amounts of various fuels which equal one kw-hr. of electric heat at different temperatures, after correcting for flue gas losses. The comparative cost is also shown in this table, based on assumed fuel costs which are given. The table assumes the same furnace construction in all cases. In actual practice, more insulation is used on electric furnaces, so that the relative cost of electricity with respect to other fuels is slightly less than is indicated by the table.

The cost of fuels is merely a guide in their selection, and should never be used alone to determine the best fuel for any given conditions. The relative convenience and cost of preparation must be carefully studied. Of even more importance is the *kind* of heating possible with various fuels, including accuracy of control, nature of surface obtainable and atmosphere required.

(Continued on page 38)



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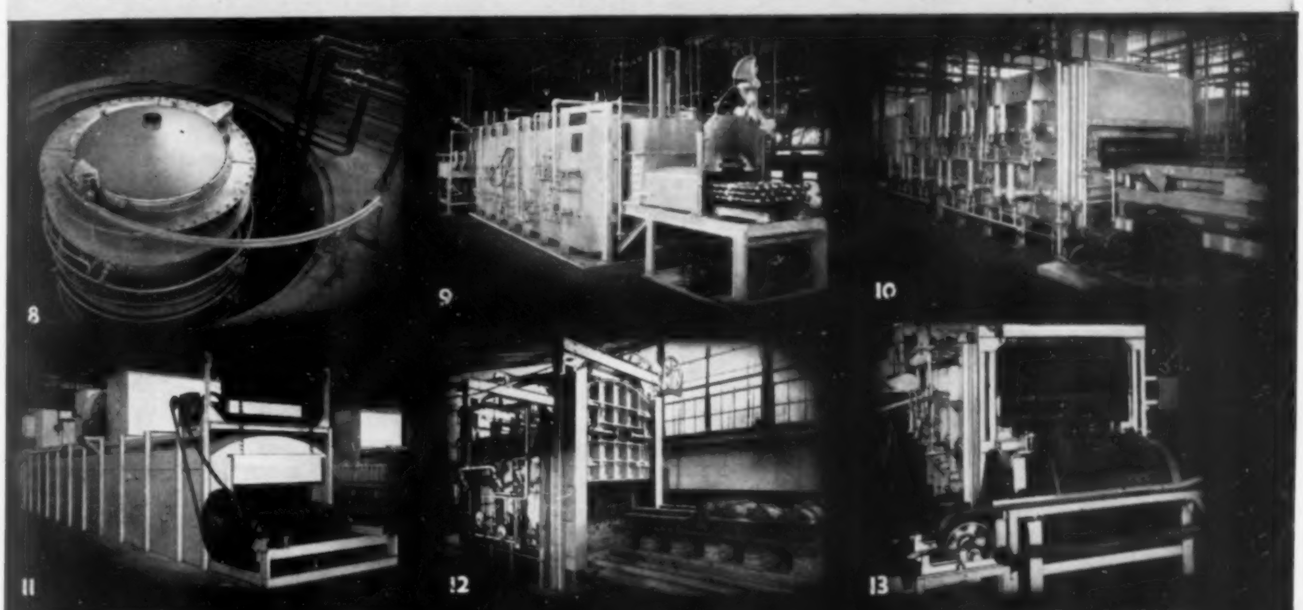


1. Continuous Roller Hearth
2. Continuous Wire Patenting Furnace
3. Batch Type Gas Carburizer
4. Bell Type Annealing Furnace
5. Clean Hardening
6. DX-Gas Preparation Unit
7. Continuous Hardening Furnace
8. Vertical Annealing Furnace
9. Eutectrol Continuous Gas Carburizer.
10. Continuous Walking Beam Radiant Tube Hardening Furnace
11. Circulated Heated Air Continuous Draw Furnace
12. Carbottom Annealing Furnace
13. Continuous Mesh Belt Annealing Furnace
14. Continuous Heating Furnace
15. Clean Hardening Furnace.

Economies are effected and quality of work improved when S.C. furnaces are used.

Surface Combustion designs and builds furnaces for either batch or continuous carburizing, hardening, drawing, annealing, galvanizing, forging. Also controlled atmosphere furnaces are available for bright annealing of ferrous or non-ferrous metals, for gas carburizing, forging, nitriding or clean hardening of steel—for either batch or continuous operation.

S.C. Engineers with their broad background of experience gained from thousands of industrial installations, will be glad to consult with you regarding your heat treating problems.

Surface Combustion Corporation

SC TOLEDO, OHIO — Sales and Engineering Service in Principal Cities

Also makers of.. ATMOSPHERE FURNACES... HARDENING, DRAWING, NORMALIZING ANNEALING FURNACES... FOR CONTINUOUS OR BATCH OPERATION

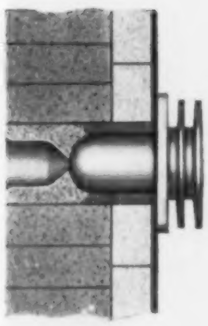
YOU ARE CORDIALLY INVITED TO ATTEND OUR EXHIBIT AT THE NATIONAL METAL EXPOSITION, SPACE No. 25-A

Surface Combustion Principles

SC

The three following important features which are incorporated in SC Furnaces, must be embodied in the construction of furnaces in order to obtain satisfactory and continuous performance.

1. Proper Combustion System.
2. Correct application of the combustion system for results required.
3. Proper design and construction of furnaces to insure continuous and satisfactory performance.



SC Tunnel Burner—1300 Series.

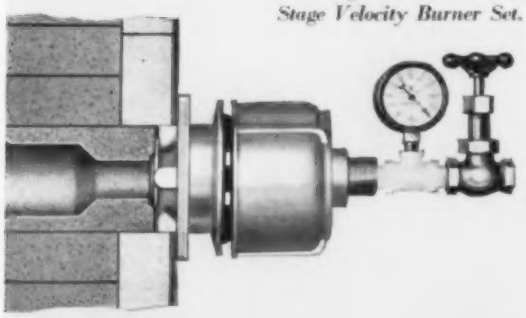
The most important factor—the firing system—embodies the fundamentals of Surface Combustion as a process which was one of the first efficient methods of burning gaseous fuels in a constantly proportioned mixture. The name originated in England where Bone, McCourt and others applied it to the catalytic action of certain metals (and later of incandescent refractory surfaces) upon the combustion of homogeneous explosive mixture of gas and air.

Professor Lucke, in America, employed the catalytic effect of incandescent granular refractory materials to increase the speed of combustion of such mixtures. This method of combustion, now known universally as "Surface Combustion," is an almost instantaneous reaction, which releases the total chemical energy of the gaseous fuels in a maximum concentration and gives the highest reaction temperature possible.

In industry, the practical application of burning gas and air by the original Surface Combustion Principle as described above, was not possible in those early days, due to the lack of suitable devices for maintaining a definite control of the gas and air mixture. Starting with this situation, SC engineers have developed the necessary equipment to perform this function automatically.

Many years of experience in research and practical application, have been the basis for the development of today's SC Automatic Proportioning Combustion Equipment, which meets almost every industrial heating need.

SC High Pressure Two Stage Velocity Burner Set.



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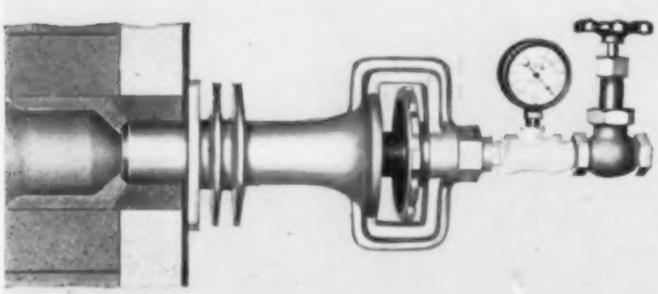
MORE THAN 400 DIFFERENT SIZES

Because no one type of burner can handle all applications, SC burners are built in 47 different types and in more than 400 different sizes. A very wide range of burner equipment is, therefore, available for whatever application you may require. The correct size and type of burner for your particular applications are assured.

SC Single Stage High Pressure Velocity Burner Set.



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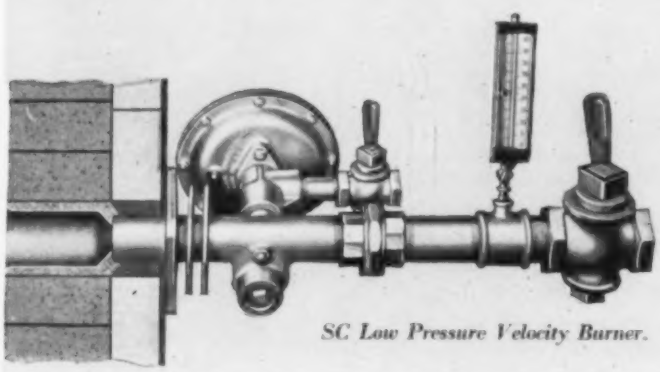
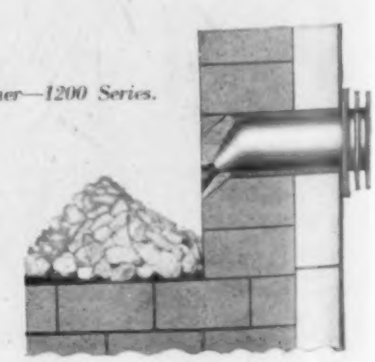
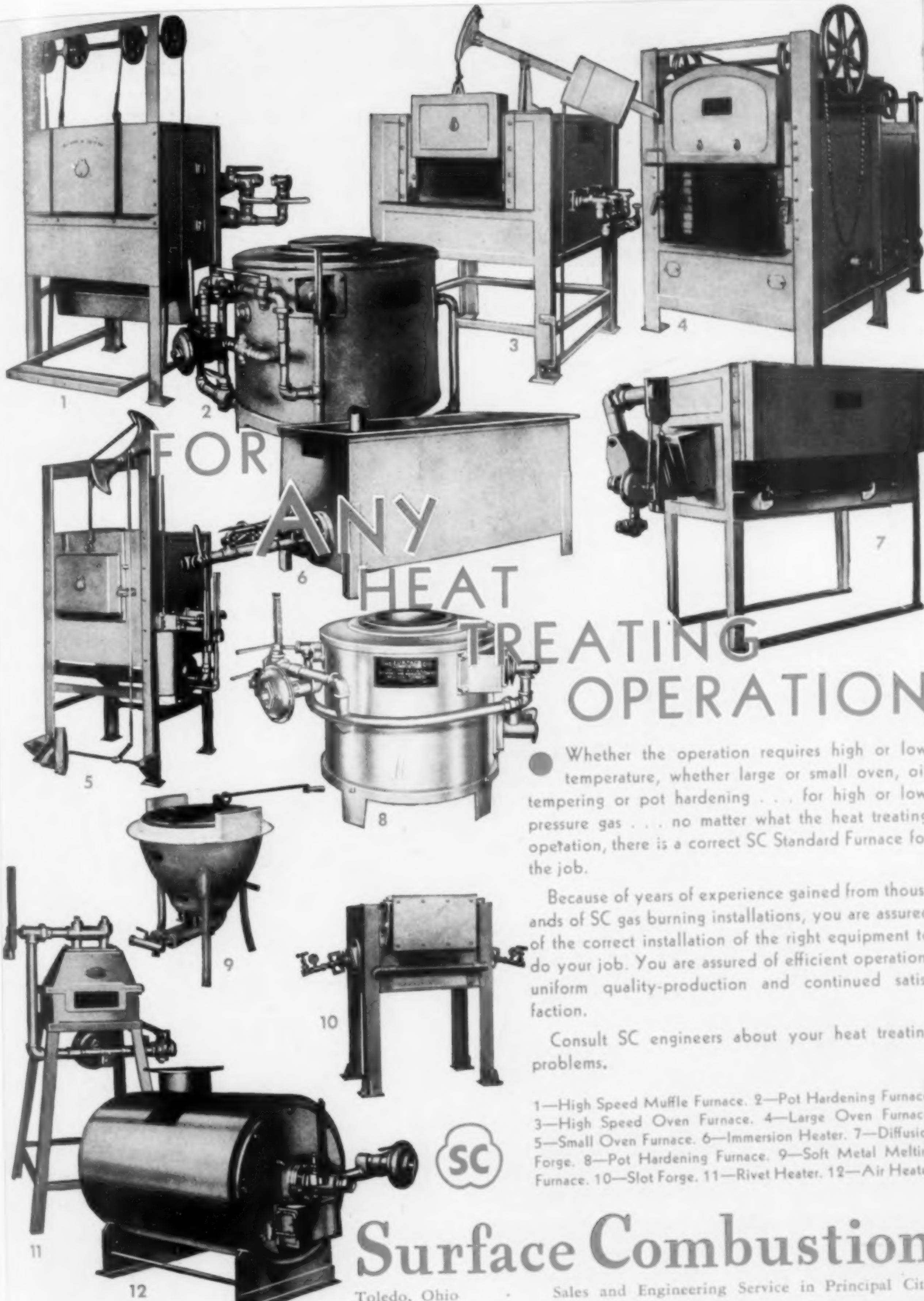


SC Low Pressure Velocity Burner.

SC Impact Burner—1200 Series.





The fundamental purpose of a furnace is to heat a given material properly, and frequently the savings from a cheap fuel are quickly lost in rejected material.

Operation Pointers

Fuel to heat cold furnace may be calculated from figures for the average rate of heat liberation in B.t.u. per sq.ft. of interior area per hr. required to heat a firebrick-lined chamber from cold to the operating temperatures in different lengths of time. Accompanying values are based on the usual practice of firing hard at the start and cutting down the fuel rate as the furnace comes up to temperature.

Hours to Temperature	B.t.u. per Sq. Ft. of Wall Heated to Operating Temperature 1000° F.	1500° F.	2000° F.
2	6000	12,000	....
4	4200	6800	13,500
6	3300	5100	8000
8	2700	4300	6000
10	2200	3800	5200
12	1800	3300	4800
14	1600	3000	4500

Furnaces lined with so-called light or insulating refractories will heat up in about one-half the time required for firebrick, with the same rate of heat input.

Operation of Oil and Gas Burners — There are several fundamental facts which should be kept clearly in mind when lighting furnaces equipped with oil or gas burners, and which, if remembered, will avoid unpleasant experiences. For all fuel fired furnaces:

1. Open all doors before lighting the furnace.

2. When lighting oil burners or gas burners of the blast (two-pipe) type, turn the air on first, then the fuel.

3. When lighting gas burners of the low pressure, proportional mixing type, always open the gas supply valve wide; all regulation of fuel is by the air flow and the ratio adjusting screw on the mixer.

4. When shutting off an oil burner, or a gas burner of any type, shut off the fuel first.

Due to the rapid ignition of most gaseous fuels, there is generally little difficulty in keeping gas burners lighted. However, when finely divided atomized oil strikes cold surfaces in the furnace, condensation takes place and separated carbon burning with insufficient air causes dense smoke. Small quantities of oil with excess air should therefore be burned until the burner block becomes red hot. A baffle in the form of a steel bar inserted from the outside and projecting in front of the burner will assist in lighting most oil burners, because it keeps the velocity of the atomized oil below that of ignition, and affords the mixture an opportunity to light before passing through the furnace chamber.

When lighting a furnace with several burners it is best to light properly one or two at a time rather than to attempt to light all burners at once. The reason is that unburned combustion gases constitute an effective fire extinguisher and several improperly adjusted burners will interfere with the lighting of others.

Drying — A new furnace after construction should be slowly dried out with gradually increasing temperature to avoid spalling and cracking. This process should take two or three days, one-third of which should be below 500° F.

After the furnace has been heated to temperature and the doors closed, the total flue area should be partially closed until a pressure of about 0.01 in. water exists in all parts of the furnace. Temperature uniformity in the furnace may be regulated at this time by adjusting the flues; in general, the flues at hotter portions of the furnace should be closed to force more gas and heat toward flues left open in the colder portions of the furnace.

Relation and Cost of Various Fuels to Electricity

Mode of Generating Heat	Furnace Temperature ° F.	Net B.t.u. per Unit	Cost per Unit ¢	1 Kw-Hr. Equivalent Fuel Units	Cost ¢
Electricity (1 kw-hr.)	all	3415	1.0	....	....
Bituminous coal (1 lb.)	1000	14,000	0.25	0.294	0.074
	1500	....	....	0.338	0.085
	2000	....	....	0.397	0.100
Fuel oil (1 gal.)	1000	140,000	5.0	0.029	0.145
	1500	....	....	0.034	0.170
	2000	....	....	0.040	0.208
Natural gas (1 cu. ft.)	1000	1020	0.04	4.03	0.161
	1500	....	....	4.63	0.185
	2000	....	....	5.45	0.218
Artificial gas (1 cu. ft.)	1000	475	0.08	8.65	0.692
	1500	....	....	9.96	0.798
	2000	....	....	11.70	0.935
Butane (1 cu. ft.)	1000	3020	0.19	1.38	0.262
	1500	....	....	1.59	0.302
	2000	....	....	1.87	0.355
Coke oven gas (1 cu. ft.)	1000	510	0.01	8.06	0.081
	1500	....	....	9.26	0.093
	2000	....	....	10.90	0.109
Producer gas (1 cu. ft.)	1000	150	0.003	30.3	0.091
	1500	....	....	37.3	0.112
	2000	....	....	46.9	0.141
Blast furnace gas (1 cu. ft.)	1000	90	0.0023	57.0	0.131
	1500	....	....	79.4	0.183
	2000	....	....	126.5	0.290

Continuous

CONTROLLED ATMOSPHERE FURNACES

Designed to Fit Your Specific Requirements

The several installations shown on this page and on the inside back cover of this issue represent a few of the various types of controlled atmosphere furnaces we have built for scale-free heat treating, brazing, and bright annealing miscellaneous ferrous and non-ferrous products in various shapes and forms.

Bright Annealing

(Left) A recent installation for bright annealing cold drawn seamless steel tubing. Other outstanding installations made for bright annealing ferrous and non-ferrous stampings, wire, sheet, strip and tubing in coils and straight lengths.

Brazing and Soldering

(Right) Two pusher type furnaces brazing miscellaneous automotive and refrigerator parts. The assemblies are automatically conveyed through the furnace and discharged completely brazed—clean and bright. Other types and sizes for various other products.

(Below) One of our standard continuous chain belt conveyor type furnaces designed for use with our inexpensive Elfurno gas atmosphere for clean and bright hardening bolts, screws and other small and medium size products.

Scale-free Heat Treating

The application of controlled atmosphere equipment to the annealing, heat treating and brazing of metals has advanced rapidly since the development of our inexpensive Elfurno gas atmosphere. It should be given consideration in the planning of all new furnace equipment or the modernization of present equipment.

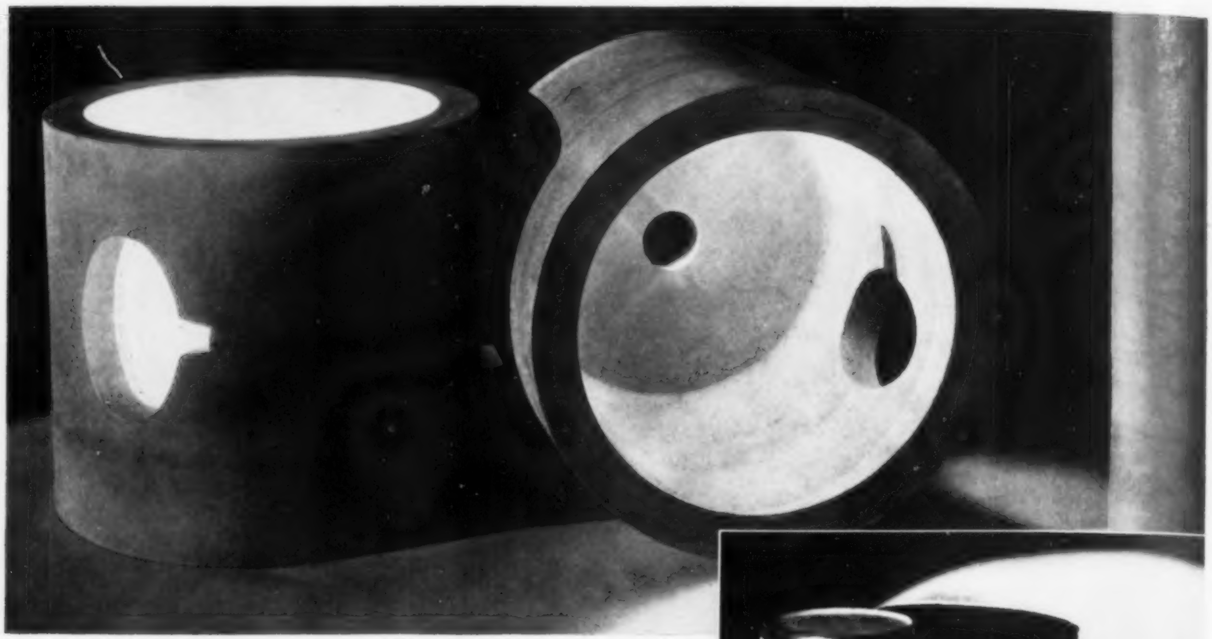
Our engineers will be glad to discuss our developments in controlled atmosphere equipment or work with you on any of your furnace or heat treating problems.

THE ELECTRIC FURNACE CO.

SALEM, OHIO.

Fuel Fired Furnaces

Electric Furnaces



Modern Melting

Requires Super-Refractories . . .

Alundum, Crystolon or Magnesia Linings

Metallurgy has progressed from a routine job to a science.

The advance in furnace design has required similar advances in the quality of the refractories employed. Norton Company has responded by developing a complete line of super-refractory materials — electric furnace products that meet the rigid requirements of modern melting practice.

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A new catalog gives full information about Norton Cements—send for a copy.

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NORTON PRODUCTS for Melting

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ALUNDUM (fused alumina)

CRYSTOLON (silicon carbide)

MAGNESIA (electrically fused)

Each of these Norton products has special chemical and physical properties, making it possible to meet the individual requirements of different melting problems.

All three products are available in three different forms:

RAW MATERIALS—
Refractory grains of various mesh sizes for making lining mixtures.

CEMENTS—
Ready-to-use bonded mixtures of high purity and refractoriness.

BONDED SHAPES—
Prefired shapes of various types, including bricks, blocks, tubes and crucibles.

ADVANCED

HARDENING, TEMPERING & TEMPERATURE CONTROL

TRIPLE-CONTROL HUMP HARDENING

Under triple control, the heat-treater has complete control of the hardening furnace.

Vapocarb controls the Hump furnace atmosphere; protects the surface of each piece; eliminates packs and coatings. Scaling, pitting and decarburization are ended. Maximum efficiency of quench, maximum grain refinement, uniform hardness of surface, and uniform depth of hardness are obtained, because the piece stays clean. No refinishing is necessary, and the average piece is as good as the best.

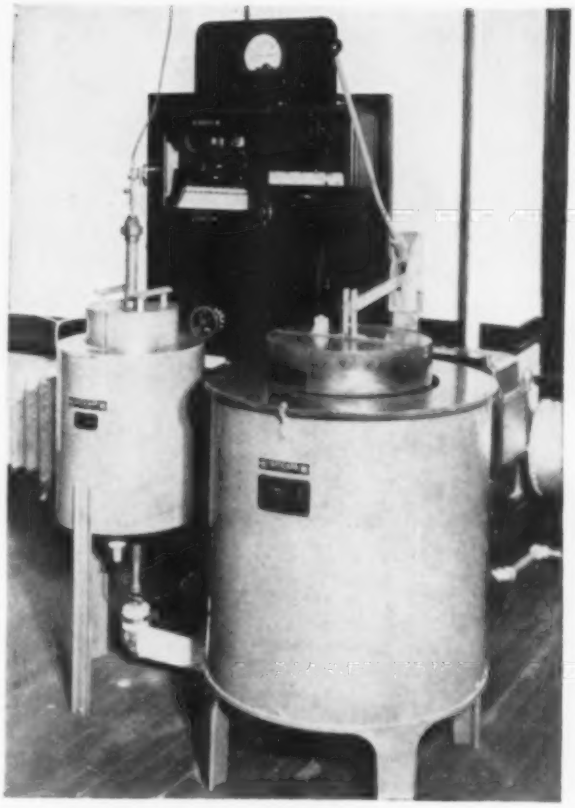
Automatic control of the rate of heating brings all sections of each piece up to the critical, through the critical and on up to the quench point together. The tool really sets its own rate of heating; distortion is reduced to the practical vanishing point.

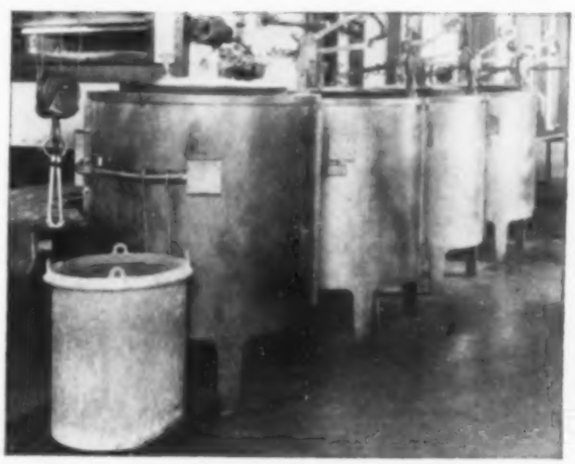
The Hump Method Control of Quench locates and records the critical range, and records the quench point. It enables heat-treaters either to duplicate quench points, or to vary them accurately and positively.

HOMO FORCED-CONVECTION TEMPERING

A new Homo Tempering Furnace has great productive capacity on very dense loads. The famous Homo uniformity, on which the success of this method rests, is not affected by a step-up in speed—work has the same close Brinell limits that Homo-Tempered work has always had. The only difference is a sharp cut in the cost of fine tempering of extra-dense loads.

The Homo that does this work, like all other Homos, operates entirely automatically. Control includes a feature that prevents overshooting. Length of soak can be varied, and soak temperatures can be raised or lowered quickly, without loss of production time. All loads can have precisely the same heat treatment, or each a special treatment.





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A Micromax Potentiometer Pyrometer of unique dependability is available for every industrial need. L&N offers a complete *line* of potentiometer pyrometers from which you can select the *form* that suits your needs. Among these pyrometers are the Micromax Strip Chart Recorder or Recording Controller, the Micromax Round Chart Recorder or Recording Controller, the Micromax Indicating Controller, the new Micromax Non-Indicating Controller, and the Micromax Radiation Recorder or Recording Controller.

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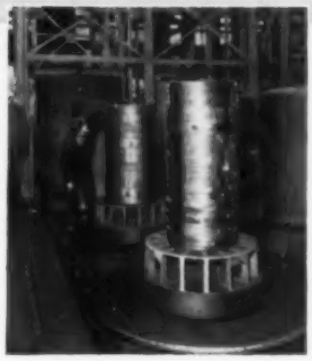

They wanted high quality — today's best sales appeal
They got it with G-E BELL-TYPE ELECTRIC FURNACES

The steel companies in whose mills these pictures were taken, now bright-anneal their coiled steel strip in G-E controlled-atmosphere, bell-type electric furnaces because these furnaces assure them of a more uniformly bright-annealed product—a higher-quality product that increases sales possibilities. In addition to high quality, these companies obtain three other important advantages. These furnaces permit quicker shipments and a greater daily output at lower cost because of their shorter annealing cycle. Rejects are fewer, since every coil in the stack is bright-annealed uniformly as a result of the even temperature distribution in the furnaces. The low temperature differential between the heating elements and the charge means long resistor life and lower maintenance costs.

For complete information on G-E electric furnaces, write to General Electric, Dept. 6-201, Schenectady, N. Y.

ANNOUNCING . . . AN OPPORTUNITY TO SEE G-E ELECTRIC-FURNACE BRAZING — HOW IT IS DONE — HOW IT CAN SAVE YOU MONEY. At our exhibit in space A-3 at the National Metal Exposition, there will be a complete G-E controlled-atmosphere electric furnace, performing copper-brazing operations on a production basis. When you see this furnace in operation, contrast its simplicity and economy with other fabricating methods.

FURNACES FROM ONE MANUFACTURER

For run-of-the-mill heat-treating jobs

For drawing miscellaneous steel parts

For high-quality, low-cost enameling work

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for heat treating

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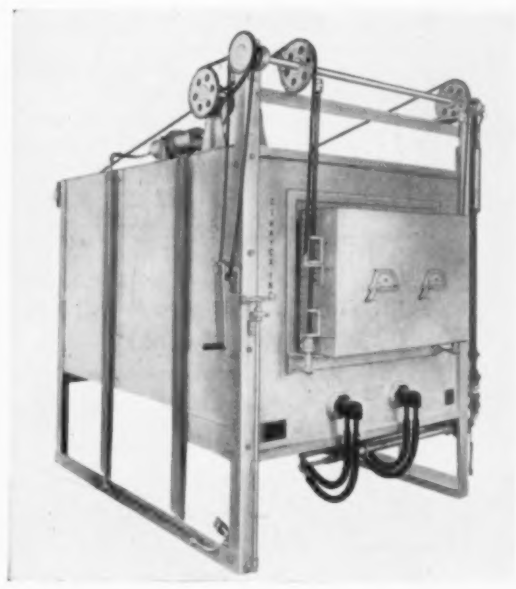

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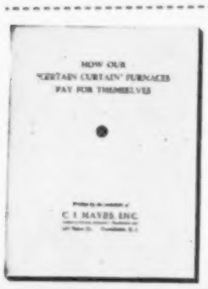

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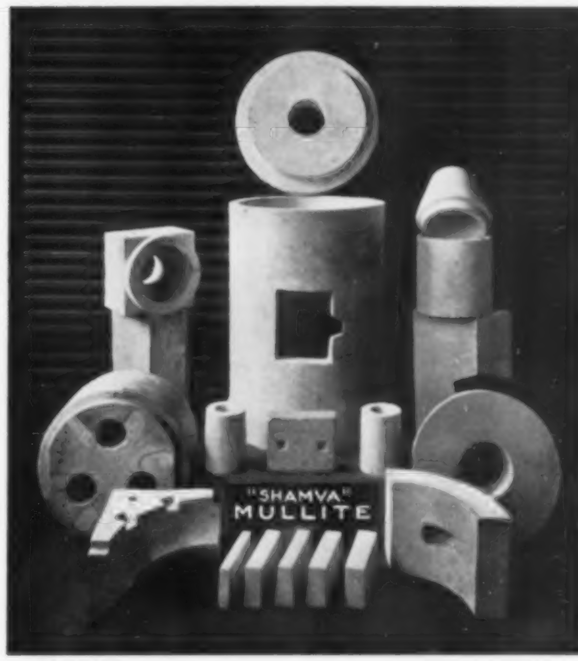
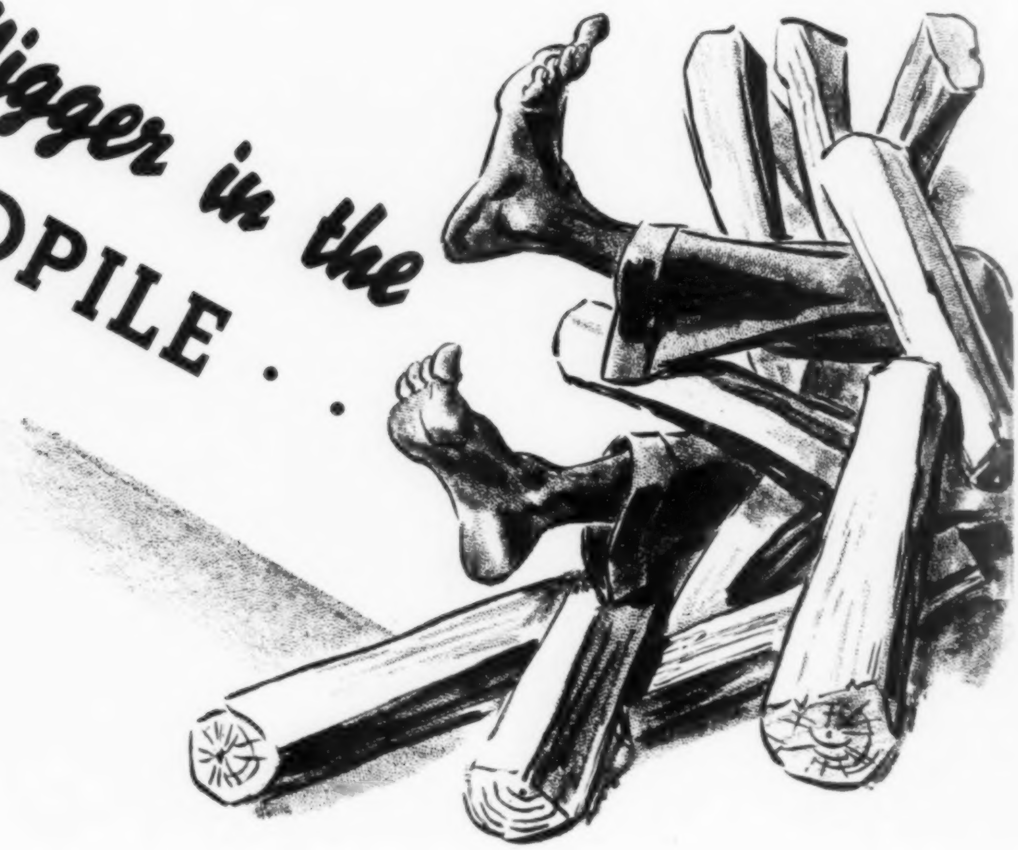

"SHAMVA"
MULLITE

The Nigger in the WOODPILE . . .



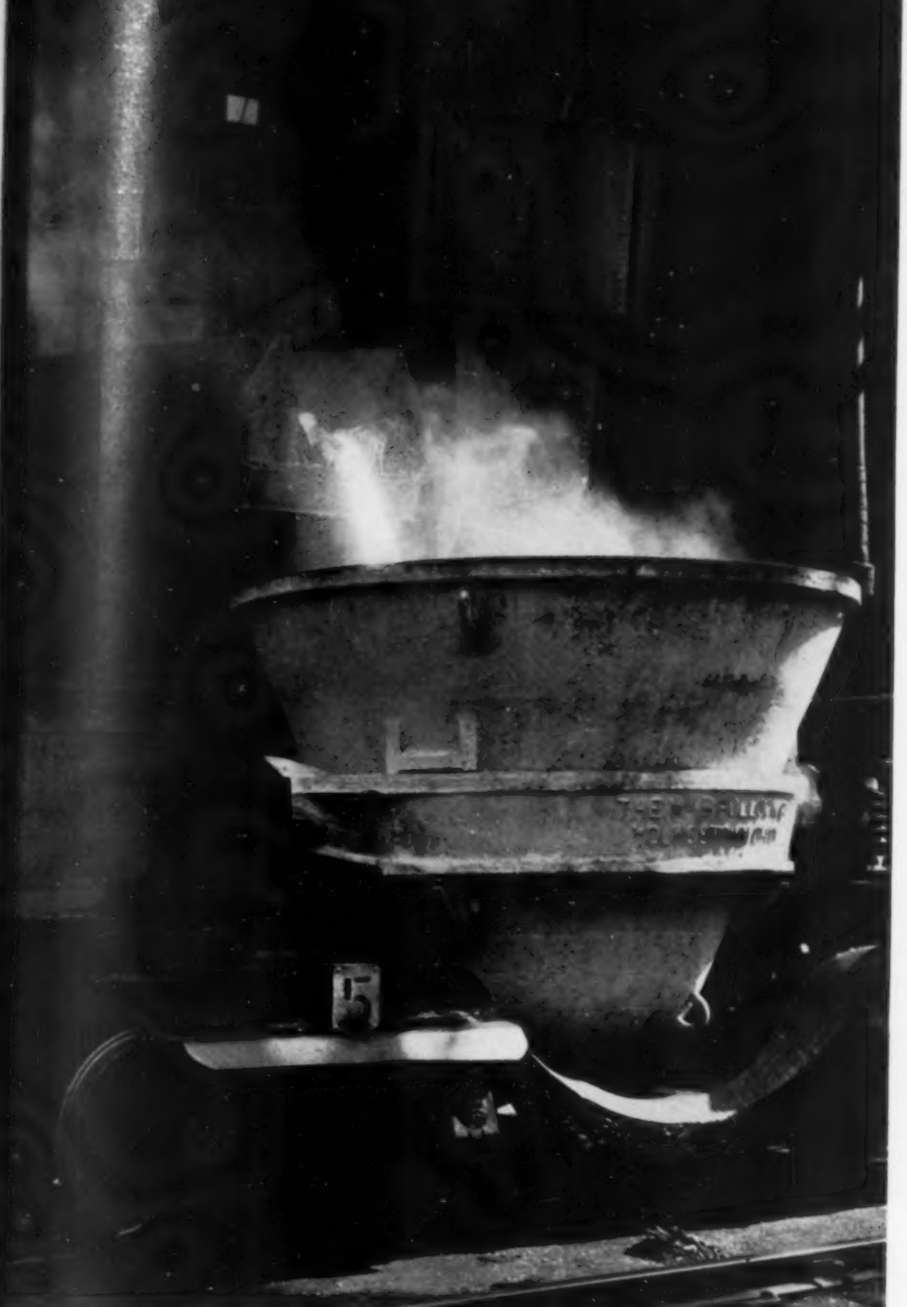
In your pyrometer circuit, your meter and Chromel-Alumel Thermocouple may be very accurate—and yet your temperature indication be in error. The "catch" lies in the error that may arise in the junction of the leads and couple. If you use "compensating leads" with your Chromel-Alumel couples, the two are of different composition, and where they join, therefore, another thermocouple exists. This junction is almost always warm and the hotter it gets, the greater the error. We don't claim this error always to be serious, but it may be and often is.

So if you use Chromel-Alumel couples, and accuracy is important to you, see to it that you also use Chromel-Alumel Leads. Thus you eliminate that thermo-electric junction mentioned above. Thus you also follow the example of Armco, Ford, General Electric and General Motors. These companies found out for themselves the possible seriousness of the above error, and so they have adopted Chromel-Alumel Leads for their Chromel-Alumel Couples. For a technical presentation of these statements ask for Folder G.P. . . . . . Hoskins Manufacturing Co., Detroit.

Hoskins CHROMEL-ALUMEL

LEADS AND COUPLES

SWIFT, SKILLED,
COURTEOUS
SERVICE
SHE is one of 100,000 operators in the Bell System—local operators, special operators for the dial system, toll operators, information operators and many others—all specialists in giving you efficient telephone service.
The alert, friendly voice of the operator is familiar to all who use the telephone. Through the years it has come to mean more than a voice. It is the symbol of politeness and efficiency.
The manner of this service is as important as the method. Even a few words can reflect a business-like, courteous attitude.
The operators in the Bell System are carefully trained. But there is something more to it than training—a spirit of loyalty and of pride in rendering an important service. This spirit is ever-present—it has brought especially high commendation in time of emergency.
Truly the telephone operators have been called "Weavers of Speech." Their swift, skilled fingers intertwine the voices and activities of communities and continents. For daily, as upon a magic loom, the world is bound together by telephone.
BELL TELEPHONE SYSTEM
There are 270,000 workers in the Bell System. The 100,000 telephone operators are able to serve you as they do because of the specialized ability of 170,000 other employees—installers, linemen, repairmen, construction crews, engineers, commercial office workers and the many thousands engaged in research, manufacture and management.



...rtesy Ford Motor Co.

CORROSION AND HEAT RESISTING MATERIALS . . .

Sound Castings and Intelligent Use Is Necessary for Satisfactory Service of Alloy Castings. . . . Both Sides Have Their Say on the Question: "What Type of Electric Resistor Is Best for Heating Elements?"

ALLOY CONTAINERS FOR HEAT TREATING IN LIQUID BATHS

PROGRESS IN THE DESIGN OF HEAT treating furnaces has been rapid during the past few years, and many basic changes have been made in methods of carburizing, normalizing and other forms of heat treatment, yet a considerable tonnage of steel parts is still hardened or otherwise subjected to heat treatment in molten salt, cyanide and lead. There is no indication at present that this operation is to be superseded by one of the newer processes and the question of selecting satisfactory containers for molten salts and lead is of great importance to those men responsible for keeping their production costs at a minimum.

Factors affecting the useful life of containers may be listed as follows (not according to order of importance):

1. Design of the container.
2. Design of the furnace.
3. Kind of fuel used.
4. Temperature of operation.
5. Length of heating and cooling cycle.
6. Composition of the metal of which the container is made.
7. Physical soundness of the container.

Let us consider each of these matters.

Of course, the correct design of a pot is of great importance. Thermal stresses induced upon heating and cooling are necessarily severe, and their proper distribution is vital to the life of the casting. For this reason containers should be made as nearly a hemisphere as possible. Where oblong pots are necessary, all corners, as well as at the bottom and flanges, should have generous radii. Working in common steel one would make the bottom of the pot much heavier than the side walls, but this is to be avoided in the manufacture of alloy containers. The low rate of heat conduction of the nickel-chromium alloys imposes severe strains where light and heavy sections join in the same casting, and is quite apt to cause cracking.

J. C. Woodson, in the symposium on the effect of temperature on the properties of metals, has called attention to the high stresses set up at flanges, due to the difference of temperature between it and the body of the pot. These stresses can be minimized by the use of a small flange resting in a separate alloy ring cemented to the top of the furnace. The small flange will reach a temperature only a few degrees lower than that of the body of the pot, and is free to expand and contract by sliding on the ring. In one installation where continuous trouble was experienced with cracking of a large flange, the life of the pot was increased five times by this means.

The first figure shows a very poorly designed pot. Castings made to this pattern repeatedly cracked at the corners and on the sides due to sharp corners and bad furnace construction. This shape was made because the customer insisted that it was necessary for his work, and to fit his furnace (a home made affair). After a series of failures, he was finally persuaded to redesign the furnace and use a larger pot with well-rounded corners. The expense of these changes was soon paid by the increased life of the pots.

By F. K. Ziegler
Metallurgical Engineer
Electro Alloys Co.
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There is no hard and fast rule known to the writer as to proportion between diameter and depth, or the smallest corner radius which can successfully be used in designing a

Alloy Pot With Flanges Too Long and Radii at Corners Too Short, Resulting in Quick Failure From Differential Expansion

pot for a specific installation. Account must be taken of all local factors affecting the life of the container, and a study made of the service records of similar installations to determine the best dimensions. Responsibility for the design should not be placed upon a draftsman, but should be shared by an experienced operating engineer, the salesman for the alloy foundry (who should be familiar with operating conditions), and the foundry superintendent. In general, it can be said that no pot should be made with less than ⅜-in. section (preferably ½ in.) and in practically every case even a thicker casting if well designed will more than pay for its greater first cost.

It is beyond the scope of this paper, and the capability of the writer, to discuss furnace design. Several responsible furnace manufacturers have made a detailed study of characteristics of pot furnaces, and can furnish a well built unit which will give good and economical service. Attention should be called, however, to the large number of home made furnaces used for heat treating. Many foremen and superintendents have their own ideas about burners and furnace design, and believe that they are saving money for their company when they assemble a furnace from scrap boiler plate and brickbats. Actually the increased fuel consumption, decreased life of the containers, and untidy working conditions result in a distinct loss, as a comparison with a really good furnace will instantly prove.

One of the commonest shortcomings of the inexperienced furnace builder is his failure to provide an efficient combustion chamber. In many such installations the flame impinges directly upon the pot, resulting in local overheating with attendant high stresses and causing premature failure through localized corrosion, particularly in oil fired furnaces. The result of flame impingement on a nickel-chromium pot is shown in the view below. Directly below the corroded area can still be seen the letters cast on the pot, proving that corrosion has not been general. The sulphur in the fuel oil, however, combined with high temperature in a small area, caused this pot to fail in less than half its normal time.

Electricity, gas, and oil are the fuels most commonly used for heating pots. The usual form of electric furnace employs heating elements distributed around the furnace walls, near the bottom and along the sides of the container. Immersion heaters are used in some installations. Choice of fuel is determined by a number of factors which will not be discussed here.

From the point of view of the manufacturer of alloy containers, electricity is the ideal heating medium, with gas and oil following in the order given, and for the following reasons: The rate of heating of a cold container has a great influence on its working life. With an electric furnace this rate can be set at so many degrees per hour, and very closely adhered to by automatic control. Furthermore the atmosphere in the heating chamber in an electric furnace is not as corrosive as in fuel fired ones. Some pots operate at temperatures which approach or even exceed the

Localized Corrosion in Nickel-Chromium Pot Caused by Impingement of Flame From High Sulphur Fuel Oil

scaling point of nickel-chromium alloys, and for such service a neutral or slightly oxidizing atmosphere in the heating chamber is advantageous.

The temperature of operation is determined by the composition of the steel to be treated and the physical properties desired in the finished part; time and temperature cannot be juggled to favor the container. The life of a pot is, of course, in inverse ratio to the temperature of operation, and at higher temperatures the life decreases in greater proportion. An unbiased analysis will show that in most cases, the use of high grade alloy pots is economical regardless of temperature.

The importance of the length of the heating and cooling cycle (particularly the heating-up time) is well understood by experienced metallurgists. It is a matter of common knowledge that a long heating period after a shutdown is necessary to avoid damage, hidden though it may be, but shortening the life of the container. In spite of this, some users repeatedly ruin pots by heating too rapidly. Care should be taken that the solid salt or lead is not melted on the bottom while the top part is still solid. Many pots are cracked in this way. Practically all large users keep their pots hot over night and through the week-end shutdown, and have found that the cost of the fuel is absorbed by the saving in wear and tear on the container. Much greater freedom of design is allowable in the case of pots which are not frequently cooled to room temperature, and the inhibitions mentioned in a previous paragraph do not apply with such force.

Excessive Corrosion on Outside of Pot Caused by Reaction Between Hot Gases and Salts Seeping Into Combustion Chamber

Three Alloys Favored

Nickel-chromium alloy pots have been used with varying success for a number of years. There seems to be very little information as to the intensity or amount of attack on these alloys by salts ordinarily used in heat treating — this refers to actual chemical solution of one or all of the alloy constituents by the molten salt itself. At any rate this chemical solution is never the cause of premature failure. It is well known that conditions at the *surface* of the bath are different and ordinarily more severe than those existing under the surface. The influences of the atmosphere, scale and oil floating on the bath, scum or slag all have a bearing upon corrosion of the container along the surface of the liquid.

An imperfect seal between the rim of the pot and the furnace often results in seepage of molten salt into the combustion chamber. This is ruinous to electrical resistors, and also has its effects on the pots set in the furnaces. Products of combustion, particularly oxygen and water vapor, usually form very corrosive compounds with the fused chlorides and carbonates of the molten salts, resulting in very rapid corrosion and premature failure of the container. A typical illustration is given in the view on this page.

Evidence has been submitted by H. Klouman in Chapter 19-A of "The Book of Stainless Steels" of selective corrosion of nickel-chromium salt pots, yet there is a distinct likelihood that such corrosion is caused by molten salt penetrating into hidden shrinkage cavities in the casting. Practically all premature failures of alloy pots are caused by corrosion of small areas, indicating physical rather than metallurgical defects. Pots which have furnished normal life are usually corroded more or less evenly at the bath line until failure occurs. See the last group of pictures.

Claims of exceptional service have been made for various special compositions of the nickel-chromium alloy system, but it is probable that these claims were based on the performance of individual castings that were free from physical imperfections. There is no evidence that major variations from the time-tested, standard, heat resistant alloys are of particular value in this field. The majority of the castings in use today as containers of molten

Pots Made of Same Alloy in Identical Service. One at left failed rapidly due to pitting corrosion at concealed casting defect; the one above failed after long service by uniform corrosion and general thinning at shore line

salts and lead is made of 35 to 40% nickel, 15 to 20% chromium, balance iron; or of 60 to 65% nickel, 12 to 15% chromium, balance iron — with the former alloy accounting for most. Many consumers who have used both alloys over a period of years are convinced that the higher nickel alloy, in spite of its greater initial cost, is the most economical one to buy, and our service records indicate that they are correct.

A large number of furnaces use oil as fuel, and for these there has been a recent trend toward the use of pots made of one of the higher chromium alloys, chiefly those in the range of 25 to 30% chromium, 8 to 10% nickel, balance iron. This alloy stands up very well in atmospheres high in sulphurous gases, but has some inherent disadvantages which are lacking in the higher nickel alloys. For example, it is not nearly so resistant to thermal shock, and unusual care must be taken to avoid rapid heating and cooling, otherwise cracks will develop.

Conflicting statements of the life of castings are obtained from users of alloy pots. Consumer A, who uses alloy I, claims wonderful service from the castings, while Consumer B, who has also used alloy I, says it is very poor, and that he has found alloy II far superior, although the chemical composition is practically identical. The natural conclusion, to a disinterested person who knows all the factors involved, is that A has had physically sound castings from the manufacturers of alloy I, while B has not. A has been lucky, and the probability is that some day he will receive a lot of unsound pots made of alloy I, and immediately change his mind about the suitability of its composition, whereas the actual reason for failure is the presence of physical defects not visible on the surface of the casting. If there is a flaw in the container which in short time allows the contents to leak through, the container is worthless, regardless of its composition.

Harmful defects found in alloy castings are *(a)* shrinkage cavities, *(b)* blowholes, *(c)* cracks and *(d)* sand or slag inclusions. Many of these defects, if visible on the surface, may be repaired by removal and subsequent welding, although major welds should never be made on liquid containers. Remarkable improvements have been made in the welding of high alloy castings, yet the service in some installations (including pot furnaces) is so severe that even the slight difference in physical properties between a large welded area and the surrounding casting may result in early failure.

Careful visual inspection will discover all *surface* defects, and experience dictates whether these defects can be successfully repaired, or whether they are of such nature that the casting should be scrapped. Regardless of the care taken in production, however, and of the skill of the workmen, some castings are produced which contain harmful interior imperfections invisible on

the surface. The possible extent of these hidden defects, together with the reasons for their existence, has been described by the writer in METAL PROGRESS for December, 1934, and June, 1935.

It is not my intention to infer that a large percentage of alloy castings are unsound. Yet every large user knows that, regardless of the integrity and good intentions of the alloy manufacturer, there is produced a certain number of castings which fail to give the expected service. In order to segregate such castings it is necessary to X-ray all castings produced for severe service, where early failure will result in heavy loss.

Experience gained over a period of two years of constant use of the X-ray in inspecting alloy pots, together with checking of service records against the files of radiographs, forces the conclusion that castings of this nature must be very nearly perfect to give long life in service, and that the composition of the alloy is of considerably less importance than the physical soundness of the casting.

NI-CR ALLOYS FOR ELECTRIC RESISTORS

By Fred P. Peters
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AMERICA, EVEN IN THESE, THE thrifty thirties, is still a pretty satisfactory dwelling place, when we stop to consider how unsatisfactory (in retrospect) it must have been in the gay nineties, and even at the start of the terrible twenties. Then toast was burned in the gas oven every morning, and each long-suffering house wife patiently heated her flatiron on a stove before leaving its delicate brown imprint on somebody's Sunday shirt. The portable kerosene stove occupied the place in the bathroom now held by the radiant heater, and what few electrically heated devices were then in use were inefficient and short-lived.

At the turn of the century many experimenters in the electrical industry — then a lusty infant — were looking for an alloy which would be a good resistor and not burn out too quickly. "German silver" was good for low temperatures, where current regulation rather than heat generation was the aim, and an unmistakable step forward was made with the use of a 25% nickel-iron alloy. While such "nickel steels" had 50 times the resistance of copper, their life to burn out a 0.030-in. wire at 1850° F. was only about two hours of continuous heating.

The widespread applications of electric heat, with all its attendant conveniences, would have been impossible were it not for the development and present-day perfection of the nickel-chromium alloys. The interesting story of this discovery and its commercial exploitation by A. L. Marsh has been clearly told in the May issue of METAL PROGRESS.

Nature exacts severe toll from materials at elevated temperatures, and few metals or alloys exist which can fulfill her requirements. Just why nickel-chromium should be able to laugh discreetly at her is an interesting question. As in many developments in the arts,

man made the discovery first, and scholars have ever since been trying to find out why it works!

Briefly, the more important properties which a material must have to be suitable for resistance heating elements are these:

1. A conveniently high electrical resistivity, that is, one that will permit the use of rod, wire or strip of reasonable cross-section with the standard voltages available. The higher the resistivity the smaller the amount of metal required, the less it costs and weighs and the less space it takes. These factors diminish in importance as the material is increasingly capable of resisting oxidation. For example, platinum does not oxidize at any temperature, and although a metal of relatively low resistivity, would be ideal for heating elements were it not so expensive.

2. A low temperature coefficient of resistivity, and one that is approximately constant from room to operating temperatures. In other words, it should have only a slight and constant increase in electrical resistance with rising temperatures.

3. Resistance to oxidation and to scaling at temperatures above a red heat. This is the prime requisite for a resistor to generate heat (unless it perchance is to be used in an inert or protective atmosphere of some kind). Heat is best transferred by radiation, and this factor is of minor importance until the element glows — hence the operating temperature of the element must be high, even though the process (such as toasting bread) goes forward at a relatively low heat.

4. A comparatively high melting point, and a narrow melting range. Operating temperatures are limited for any application to a maximum no closer than 250° F. to the melting point of the alloy. For service at 2100° F., therefore, the only suitable materials are those that have a "complete freezing point" higher than 2350 or 2400° F. This allows some margin of safety in the event that the resistor should be overheated, or the line voltage should fluctuate.

5. Good properties at high temperatures, such as sufficient strength to resist sag or creep, toughness to resist mild accidental shock, small coefficient of expansion to resist thermal shock or rapid fluctuation in temperature, the absence of pronounced grain growth, and of permanent increase in length.

6. Ability to manufacture to rigid specifications, and be drawn into fine wire of excellent surface or be rolled into thin ribbons. This also includes enough ductility to withstand severe forming operations in the cold state.

7. Reasonable cost.

Various Resistors Now Available

As before noted, resistance materials were not at all satisfactory until 1906 when A. L. Marsh patented the family of nickel-chromium alloys containing more than 75% nickel and less than 25% chromium. Today such alloys and their iron-containing modifications, by virtue of their peculiar suitability, have been accepted as standard for heating element service.

Their position, however, is being attacked by the iron-base alloys, notably iron-chromium-

Data About Interesting Electrical Resistors

Name	Typical Composition (Per Cent)	Resistance Ohms per ⊙ Mil-Ft.	Temp. Coefficient per °F. to 212	Resists Oxidation Below (°F.)	Begins to Melt at (°F.)	Strength at High Temp.	Growth at Working Temp.	Relative Prices
Low temp. resistors								
Nickel-silver	18 Ni, 60 Cu, 22 Zn	190	0.00011	850	2030	Poor	Considerable	Low
Nickel steel	25 Ni 75 Fe	380	0.0007	1100	2650	Fair	Considerable	Low
Cupron	45 Ni, 55 Cu	294	0.000006	950	2350	Good	Slight	Low
Nickel-chromium	80 Ni, 20 Cr	650	0.00006	2100	2540	Excellent	Slight	Medium
	60 Ni, 15 Cr, 25 Fe	675	0.00007	1830	2460	Excellent	Slight	Medium
Low nickel	30 Ni, 20 Cr, 50 Fe	600	0.00017	1560	2550	Good	Slight	Low
	28 Cr, 72 Fe	400	0.0006	1750	2375	Poor	Considerable	Low
Iron-chromium-aluminum	80 Fe, 15 Cr, 5 Al	750	0.00005	2100	2910	Poor	Excessive	Low
	68 Fe, 27 Cr, 5 Al	850	0.00002	2275	2780	Poor	Excessive	High
	55 Fe, 37.5 Cr, 7.5 Al	1000	0.00012	2600	2830	Fair	¼ in. per ft.	High
	67 Fe, 25 Cr, 5 Al, 3 Co	900	0.00003	2375	3000	Poor	Excessive	High
Molybdenum		33	0.0022	1300	6510	Good	Slight	Very high
Platinum		72	0.0021	3190	3190	Good	Slight	Very high

aluminum in various proportions either with or without cobalt, mostly of foreign but some of American invention and manufacture. These new alloys are higher in resistivity than the conventional nickel-chromium combinations, have frequently a very much lower temperature coefficient of resistivity, and are often more resistant to oxidation and scaling at higher temperatures. However, their usefulness is markedly circumscribed by one or more disadvantages which will be noted later. At present, it is doubtful that their challenge to nickel-chromium heating elements can be a serious one except at temperatures clearly beyond the 2000° F. safe limit for nickel-chromium. (It is, of course, possible that the future may bring modifications and improvements.) Also some of them have properties that favor their use at high temperatures where they do not carry much electrical current.

Compositions of various materials which have been, or are in use as resistance wire or rods for electric heating, are contained in the table, and an indication of the manner in which each meets the previously listed requirements.

Nature of Oxide Coatings

It would take us too far afield to present an adequate discussion of the question why some metals resist oxidation at high temperatures, especially since the latest thought on this matter has been outlined by Messrs. Heindlhofer and Larsen in Metal Progress last September. It may be said that the noble metals, such as platinum, do not form a scale because if any oxide did form it would immediately dissociate, the oxygen pressure (dissociation pressure) of the oxides being greater than the oxygen pressure in the atmosphere. All the base metals do form stable oxides — that is, those whose oxygen pressure of dissociation is infinitesimal, far less than the oxygen pressure in the atmosphere. Whether such metals are oxidation resistant, therefore, depends on the nature of the oxide coating which must form. Likewise the oxide must not evaporate (like tungsten's or molybdenum's) and leave bare metal behind, or have a low melting point and drip off (like iron oxide at white heat). It should, to be protective, be continuous, relatively impervious to oxygen, cling tightly, and have about the same coefficient of expansion as the metal itself.

The "protectiveness" of a metallic oxide may therefore roughly be defined as its ability to obstruct the course of further oxidation, and especially to retard the rate of wastage, whether the heating be continuous or intermittent. It has definitely been shown that the ability of an oxidizable *pure* metal to resist progressive oxidation is a function, not of any chemical property of the metal itself, but of the physical characteristics of the oxide formed. In those metals that are protected, the rate of oxidation decreases as time goes on. As the oxide forms it offers increasing impedance to the further diffusion of oxygen to the unoxidized metal beneath. In general, it may be said that the metals with protective oxides are those whose oxides occupy a greater volume than the metal they replace.

According to Pilling and Bedworth these facts may be reduced to a relatively simple mathematical expression for pure metals. If W be the molecular weight of the oxide, and D its density, and if w be the formula weight of the metal and d its density, then $Wd \div wD$ will be greater than 1.0 for metals whose oxides are protective, and less than 1.0 for those whose oxides are porous. Actual calculation gives the specific values below.

Sodium	0.32	Zinc	1.59
Potassium	0.51	Nickel	1.68
Lithium	0.60	Copper	1.70
Strontium	0.69	Iron	2.06
Calcium	0.78	Manganese	2.07
Magnesium	0.84	Cobalt	2.10
Aluminum	1.28	Tantalum	2.10
Cadmium	1.32	Silicon	2.20
Tin	1.33	Tungsten	3.30
Zirconium	1.55	Chromium	3.92

Thus, we have available a rough method of predicting which of two classes of oxidation a pure metal will undergo, whether the oxide will "build up" protectively and retard the subsequent rate of oxidation or whether scale will form and continue forming at the same rate as time goes on. The figures given, however, yield no exact indication as to the extent of the protectiveness, and in truth, the factors that determine the relative abilities of the protective oxide-forming elements to resist oxidation are not completely understood. We do know, however, that nickel is more resistant than iron, and that a few per cent of chromium, silicon, or aluminum, when added to them, may increase their oxidation resistance several hundred fold.

While these observations apply to pure metals, it is true that the properties of pure metals are frequently conferred on alloys made of them. Thus it is that chromium successfully inhibits the oxidation of iron when alloyed therewith. This is true to an even greater extent of

Bright Annealing in One of Its Most Difficult and Precise Forms Must Be Practiced on Heavily Cold Drawn Nickel-Chromium-Iron Alloy Wires

chromium alloyed with nickel. Chromium itself is oxidized quite readily and the oxide formed tends to surround the unoxidized particles of iron or nickel and protect *them* from oxidation. At the same time, the chromium oxide, because of its greater volume, tends to fill any voids and so slows up the diffusion of oxygen to the inner layers of metal.

With respect to the *path* of oxidation, Smithells has shown in his book, Impurities in Metals, that such diffusion of oxygen during the life of a resistance wire takes place along the grain boundaries — regions of impure or disorganized crystalline material which are preferentially attacked. The importance of purity and grain size in slowing up oxidation should therefore be noted. It is a fact that carefully made nickel-chromium alloys, which are solid solution alloys whose crystal structure closely resembles that of an austenitic steel, possess little or no impurities or insoluble constituents at the grain boundaries. In contrast to this the ferritic, iron-base, heat resistant alloys do not have equal solvent power for many of their minor constituents, which appear at the grain boundaries with damaging effect.

Where intermittent heating is a part of the service requirements, as it almost always is, the resistance of the metal to scaling depends to a considerable extent on the coefficient of thermal expansion of the oxide. The closer the oxide's coefficient of expansion is to the alloy's, the greater will be the resistance of the scale to flaking or cracking during repeated heating or cooling in operation. It is characteristic of nickel-chromium that the oxide formed possesses a coefficient of thermal expansion which approximates fairly closely that of the original alloy.

Having in view the above considerations, and turning again to the tabulation of commercial resistors, only the nickel-chromium and the iron-chromium-aluminum alloys may truthfully be said to be of first class as regards resistance to oxidation and scaling.

(Platinum is in a class by itself. Physically it is the best heating element, notwithstanding the inconvenience attendant to its low resistivity, and is used in small devices which must produce so high a temperature that nothing else will do, regardless of expense. Molybdenum finds application at very high temperatures, but can only be used in protective atmospheres.)

Ni-Cr Versus Cr-Al

Experience of some years with three of the iron-chromium-aluminum family of alloys has shown that, in spite of the claims made, they do not stand up quite so well in service at 2000° F. as do the nickel-chromium alloys, especially the improved 80 Ni, 20 Cr alloys. It is true that these particular iron-base alloys possess great resistance to oxidation at even higher temperatures, but an unfortunate feature is their excessive grain growth after prolonged use at high temperatures. If this happens to resistance wire, it is manifested by brittleness, a permanent increase in length of the element, which as time goes on, increases the electrical resistance, decreases the wattage and the temperature of the unit at constant voltage.

Another unfortunate feature of the iron-chromium-aluminum alloys with or without co-

balt, as compared to nickel-chromium alloys, is the lower strength at high temperature possessed by the former. In service this results in sagging whenever the element is not completely supported. At 2000° F., for example, a chromium-iron-aluminum alloy will have a tensile strength not greater than 1500 psi., whereas nickel-chromium at the same temperature may sustain a tension of over 6000 psi. without breaking.

The presence of large amounts of aluminum in the complex alloys, while largely responsible for their excellent oxidation resistance, reduces the ductility of the cold material to a very low figure. Thus, the elongation of the iron-chromium-aluminum-cobalt alloy, as delivered, averages 14% in 10 in., whereas the elongation of annealed nickel-chromium alloy may be as high as 35%. For this reason, the former alloys are rather difficult to fabricate in the cold state, and tend toward brittleness unless great care is taken in all stages of processing. Shapes are difficult to form and helical coils made of such alloys do not possess the perfectly bright, smooth surface, and the even "stretch" characteristic of nickel-chromium coils.

The alloy containing 55% iron, 37½% chromium and 7½% aluminum has recently been put on the market by an organization of outstanding ability and was described by S. L. Hoyt, one of the patentees, in Metal Progress for July. No doubt it is an improvement over former alloys of this family, but even Dr. Hoyt does not claim any great amount of ductility for the material, noting that it is hot rolled or swaged to 8-gage rods, and then hot formed into serpentine bends or helixes required for the application. It is probable that the new alloys will be most effective at temperatures above the safe limit for nickel-chromium resistors, as for heating forge furnaces, heat treating high speed steel and in burning ceramic ware, and thus come into direct competition with non-metallic resistors of the silicon carbide type. Even here there is a serious problem to be solved in the production of inexpensive refractories which will offer proper support to these hot elements and not soften under the heat or react with the metal and damage its characteristics.

We may also quote what Prof. M. A. Hunter of Renssalaer Polytechnic Institute says about the iron-chromium-aluminum resistor alloys in The Book of Stainless Steels, page 510:

"These alloys are finding applications in situations where high resistances are required in the minimum of space — for instance, radio resistances at room temperature. They can operate satisfactorily, too, at high temperatures because the alloy resists oxidation to a marked degree. They do not resist sagging and deformation as well as the nickel-chromium alloys, although they have a markedly higher electrical resistance and can be operated at a higher temperature. By reason of their high content of aluminum, they are more difficult to draw than nickel-chromium alloys. In spite of this they are being drawn for radio service to wires as fine as one mil."

The foregoing statements are not meant to be a sweeping indictment of the iron-base chromium-aluminum alloys, with or without cobalt. On the contrary, they constitute a most useful group, and should find considerable application for *(a)* heating elements operating at temperatures greater than 2200° F., where the cost of platinum would be prohibitive; *(b)* heat resistant applications not involving the passage of electric current through rod, wire or strip of the material; and *(c)* resistance elements not used for heating purposes, where their high electrical resistance makes possible to the equipment designer a considerable saving in space. For most industrial and domestic heating applications, however, nickel-chromium, because of its excellent heat resisting properties, its mechanical stability at high temperatures, and its efficiency and convenience should be found more suitable.

For High Temperature Resistors the "Life Test" Must Be Made in a Manner Agreed to by the Various Manufacturers and Embodied in an A.S.T.M. Specification

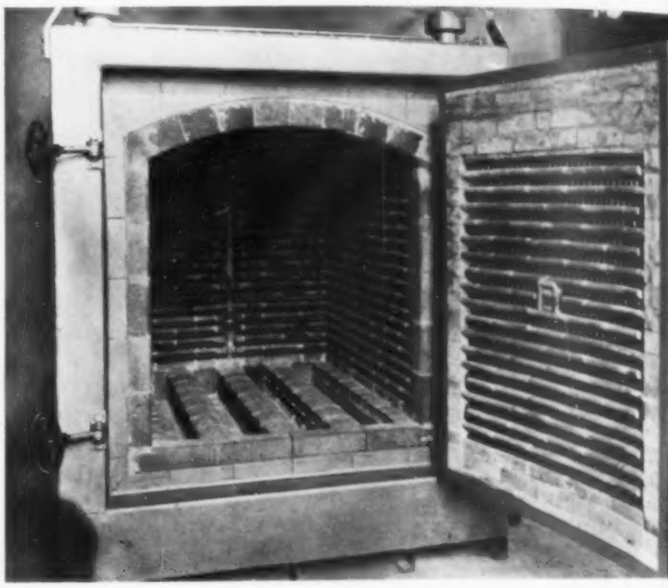
ALLOYS GOOD AT TEMPERATURES ABOVE 2100° F.

ENGINEERS AND DESIGNERS OF ELECTRIC furnaces and other electric heating units who are demanding higher temperatures and more compact units will be interested in a group of chromium-aluminum-cobalt-iron alloys first noted in METAL PROGRESS in December, 1931. Experience with them in European countries has been excellent. Although they are of an entirely different analysis from the nickel-chromium or nickel-chromium-iron alloys commonly used for electrical resistors, in what follows comparisons will be made to the 80-20 Ni-Cr alloy to establish the relative values.

This new group of alloys is known as Kanthal. They are useful for resistance purposes at medium and high temperatures and consist of chromium, aluminum and cobalt totaling about 35%, the remainder being almost pure iron. No nickel is used, and the properties and structure are considerably different from the nickel-chromium. (Editor's Note: The Kanthal family contains the analysis noted by Mr. Peters in his article immediately preceding as 25% Cr, 5% Al, 3% Co, balance iron. This differs from the alloy described by Dr. Hoyt in METAL PROGRESS for August, which contains no cobalt and about 37.5% Cr, 7.5% Al, balance iron.)

The alloys were originally developed with the idea of making resistance materials of less expensive metals and for operating temperatures much higher than possible with nickel-chromium. The first commercial installations were in electrical furnaces and the use has now increased to include all types of electric heating units, domestic and industrial, large and small. The percentages of chromium, aluminum and cobalt are varied to produce three grades suitable for safe operating at increasing temperatures, thus: Alloy D, 2100° F.; Alloy A, 2375° F.; Alloy A-1, 2450° F.

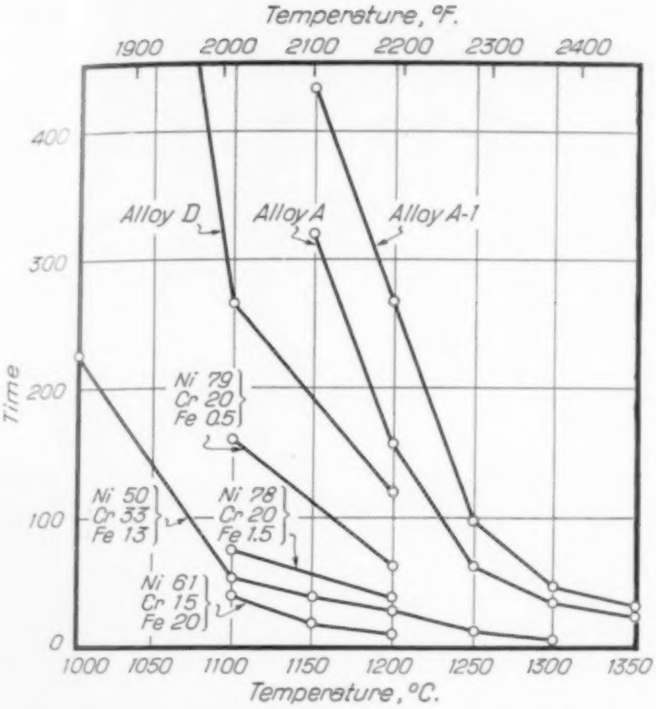
By Gunnar Nordstroem
Chief Engineer
Aktiebolaget Kanthal
Hallstahammar, Sweden



Furnace for Firing Ceramic Parts at 2200° F. Operated by Swedish General Electric Co. since February, 1933, without failure of ribbon resistor units in side walls, hearth or roof

A large number of life tests have been made at all useful temperatures. Apparatus and methods used for this work are identical with that recommended by the American Society for Testing Materials (specification B75—33), except that at high temperatures the wires are subjected to no other load except their own weight. Average results from several hundred tests produced the graph on the next page.

The specific resistance is considerably higher than in nickel-chromium, and for the three grades is as follows: Alloy A-1, 872 ohms per circular mil foot; Alloy A, 837 ohms; Alloy D, 812 ohms; and for 80% nickel, 20% chromium, 650 ohms. The temperature versus resistance curve is almost a straight line, slop-



Average Results of a Number of Life Tests Following A.S.T.M. Standard Practice at Various Temperatures

ing upward very slowly. Resistance increases only 1% at 650° F.; 2% at 1000° F.; 3% at 1475° F.; 4% at 1650° F.; 5% at 2000° F.; and 6% for Alloy A at 2375° F.

Specific gravity is lower than for nickel-chromium alloys, being 7.15 instead of 8.35.

Many early difficulties were experienced in cold rolling and drawing, but these have now been surmounted. Ribbons are the usual form used for high temperature furnaces, wires of proper size for industrial and domestic heating elements. Wire is drawn as fine as one mil.

Tensile properties of drawn wire in medium size are as follows: Elongation in 10 in., about 14% and reduction of area about 64%. Tensile strength falls off sharply on heating, thus: 70° F. 110,000 psi.; 129° F. 15,200; 1650° F. 4,200; 2010° F. 1,520 and 2375° F. 380 psi.

Due to this reduction in tensile strength at high temperatures, it is necessary to provide proper support for elements. Corrugated elements hanging from knobs on the sides of the furnace are not suitable above 2000° F. as the element can elongate by its own weight. The most satisfactory construction is when the element is laid in troughs or shelves (as shown in the half tone) formed by protruding ends of header brick. In this view the ribbon is wavy, like a sine curve, and presents a broad surface for radiation. Similar wall construction would be suitable for helical coils of wire.

A typical roof construction for such furnaces would require inverted T-brick projecting downward to form rather broad recessed slots in the roof, and in these slots would be placed the strip bent into a series of reversed "hairpins," the bends resting on the brick. This exposes one edge of the ribbon downward toward the work to be heated.

Welded terminals can best be made by the carbon arc without flux. Most fluxes combine with the alloy at high temperatures and produce undesirable after-effects.

For service at temperatures above 2000° F., the bricks should be a high quality refractory made of pure alumina or sillimanite, free from quartz and iron oxide. Bricks of ordinary fire-clay, covered with a burnt-on layer of pure alumina where they come in contact with the hot metallic elements, are excellent.

The furnace shown at the head of the article is rated at 70 kw. and was built by the Swedish General Electric Co. It has been in operation since February, 1933, for the firing of ceramics at an average temperature of 2200° F. The elements are made of ¾ x 0.080-in. strip, corrugated and placed on edge, as described above. Inside dimensions of the furnace are 40 in. wide by 65 in. deep by 42 in. high. The surface load on the elements is 8 watts per sq.in.

Similar furnaces have been operating at the same and higher temperatures since 1932 in sizes up to 300 kw. per furnace without one failure of the elements. A number of these are used for the treating of austenitic stainless steel. Others are forging, enameling and pot type furnaces.

Since these alloys are now drawn and rolled in the same sizes as nickel-chromium (including the smallest wire and ribbon) they are widely used in Europe for domestic appliances, particularly where quick boiling of water is desirable. By taking advantage of the high specific resistance and high surface load, it is possible to manufacture very compact and high capacity units. The alloys have the quality of retaining a constant resistance after long use, which is particularly valuable in a domestic unit where reduction of wattage destroys its usefulness.

Consequently this family of alloys will open a new field for builders of furnaces, domestic appliances and electric heating units of all types. The use of higher element temperatures and higher watt densities combined with higher specific resistance and lower specific gravity should permit electric heat to replace other mediums where they have not been entirely satisfactory.

LARGEST EXHIBITORS IN OUR LINE AT THE STEEL SHOWS— *for* 16

MOST of the old timers in the heat treating game have taken in one or more of the A.S.S.T. and A.S.M. annual Steel Shows, many have seen them all. They will tell you that no alloy company at any time during the past sixteen years ever showed a third as many castings as General Alloys have shown every year. General Alloys' exhibit always includes scores of Q-Alloy and X-ite castings borrowed from the largest alloy installations in the world, with full service records.

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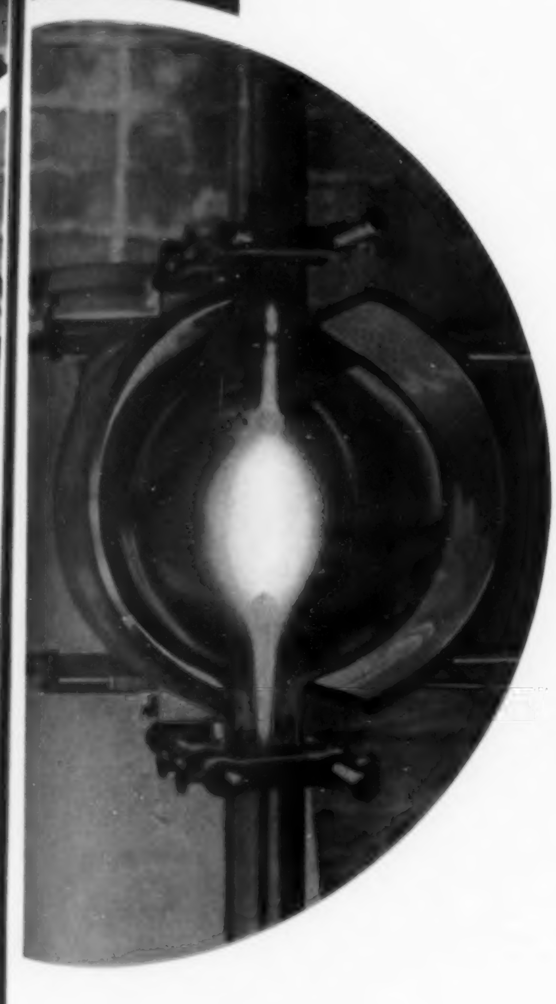

NEW PERFECTION of URFACE and of STRUCTURE by MICHIANA CENTRIFUGAL CASTING

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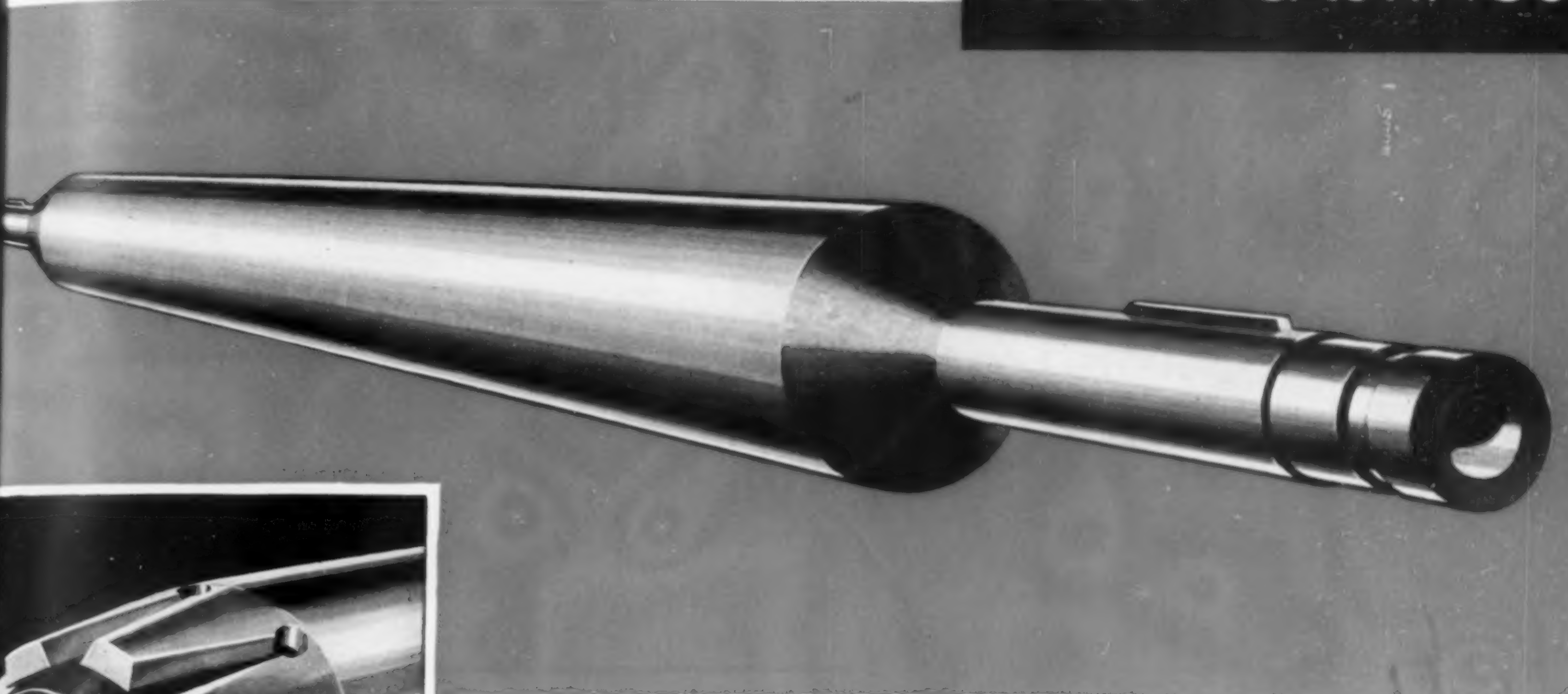

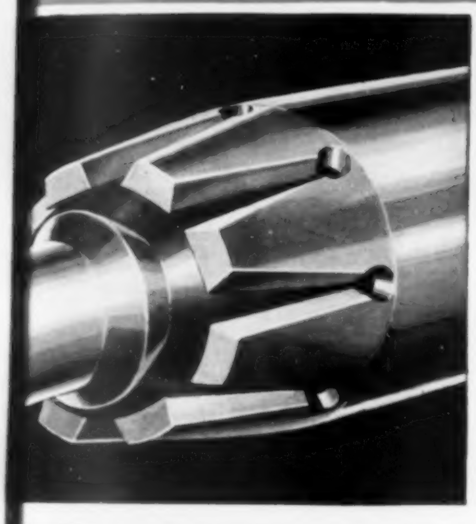

PATENTED METHOD of ATTACHING TRUNNIONS MULTIPLIES STRENGTH

•

Illustrated above is the Michiana patented method of attaching trunnions to a cylinder. Funnel-shaped end of trunnion is made to fit closely into cylinder. End of cylinder is slotted for swaging over trunnion end. All seams are then electric welded making not only a neat looking job but one of very superior strength and serviceability as compared with the ordinary method. Illustration is of assembly before swaging and welding are completed.

MICHIANA metallurgists are constantly improving the art of alloy casting. Every year, Michiana Castings are improved in surface, structure, performance.

The roll for steel normalizing furnaces shown above is an example of a recent Michiana advance. The barrel is cast on the Michiana Centrifugal Casting Machine which makes possible a far better surface than could be obtained by any other method—perfect surface being advantageous in this instance to avoid scarring the steel sheets as they pass over. Uniform structure through and through is assured by Michiana centrifugal casting. And a new patented method of attaching the trunnions multiplies the strength of the roll.

The Michiana method of centrifugal casting will make similar improvements in surface and structure of any tubular-shaped product—pots, retorts, cylindrical liners, tubes, etc. And Michiana ingenuity is constantly giving customers unlooked for superiorities in strength, efficiency, and service.

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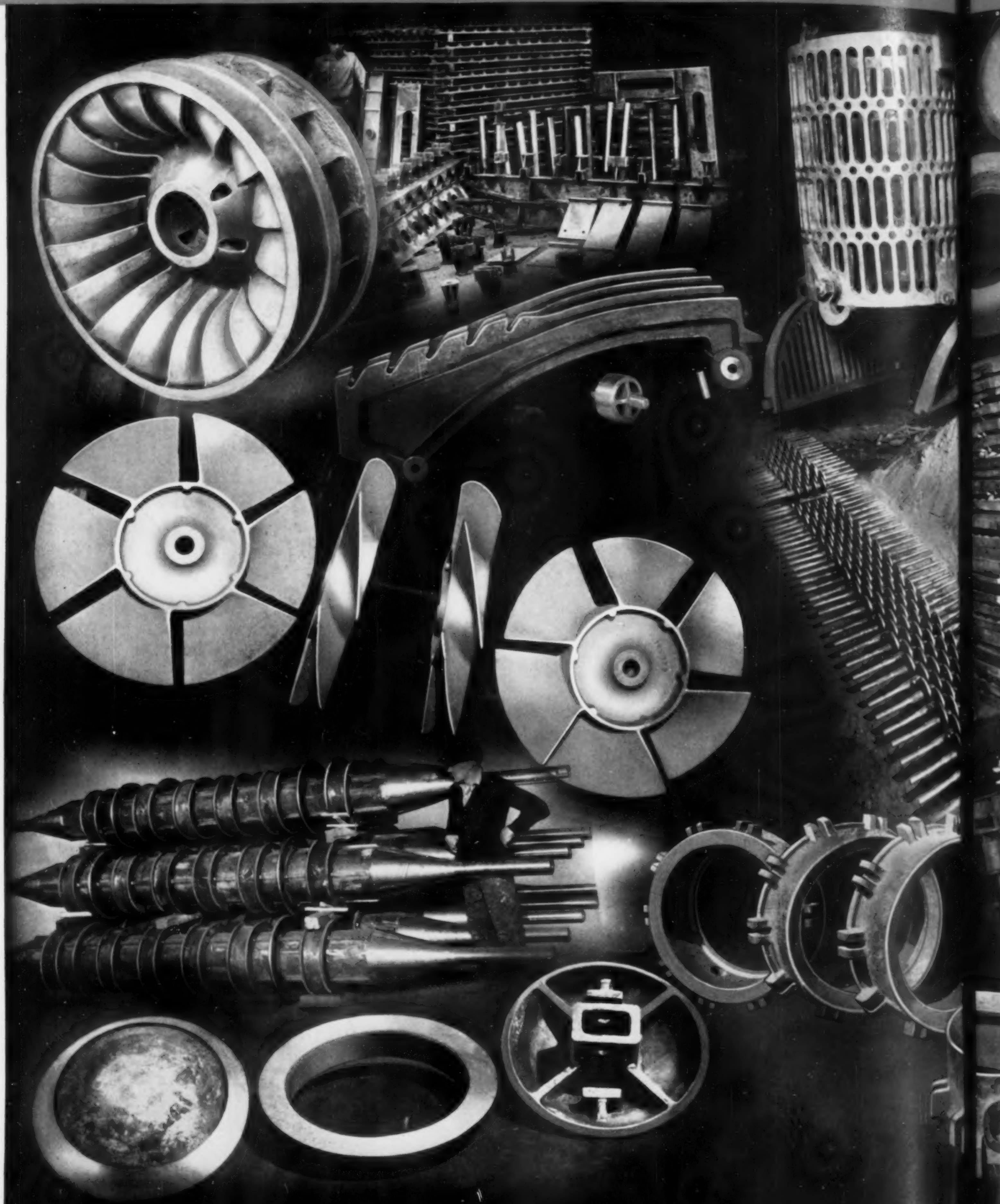

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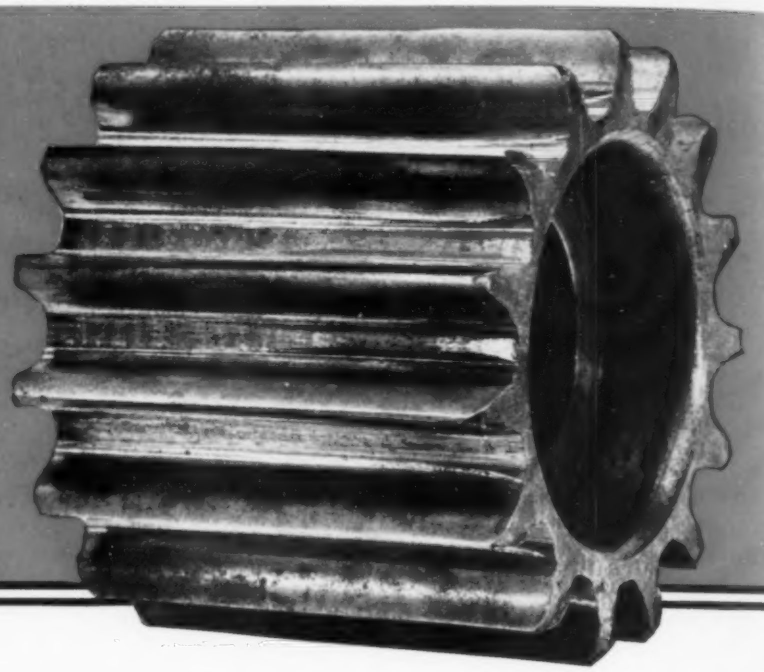

Engaging with Carburized, File-Hard Bull Gears . . .

In the files of Horace T. Potts Company, Philadelphia, are literally hundreds of instances of the long service of *Elastuf*, an oil hardened and tempered chromium Vanadium Steel. The trolley car motor pinion illustrated above is typical. After 225,000 miles—five times the average life of pinions made of other steels—it was still in good condition and performing satisfactorily. Note the tooth contour and the fact that the surface shows no breakdown.

Scores of these Vanadium Steel pinions, machined from Elastuf Type A Heat Treated Steel, without heat treatment after machining, are standing up in trolley car service. Their dependability furnishes another instance of the long wearing qualities of Vanadium Steels.

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by Margaret Bourke-White for Ludlum Steel Co.

ALLOY AND TOOL STEELS

Progress in This Field, as Recorded in 12 Issues of Metal Progress, Includes the Introduction of a Number of Low Alloy Steels for Severe Service From Sub-Zero to Elevated Temperatures, and a New High Speed Tool Steel Wherein Much Tungsten is Replaced by Molybdenum

Don't let inertia encumber your business

Business philosophy associates "inertia" with the ever-debatable policy of "Let well enough alone." Too often this inertia is the result of a groundless fear of upsetting routine, changing specifications and inspection standards, resetting machines, recasting work sheets, ironing out new processing kinks . . . temporarily slowing up production.

Nevertheless, executive and sales heads ever have before them the vital problems of competition and consumer preference. They see clearly the dangers of inertia. But they are not always technicians. Hence, they must look to you — metallurgist, engineer, production expert — to share the responsibility for Progress in raw material and product.

Steel — together with iron, is the basic raw material of American business. Admirable as are many of the more familiar alloying elements for giving steel this or that added quality, inertia threatens when executive, engineer and production manager are "entirely satisfied" and content to ignore the metallurgical progress still being made in alloyed steels. In fact, the past ten years have witnessed some of the greatest of all advances . . . with Molybdenum steels probably outranking all others.

"Moly" not only improves ordinary carbon steel, but actually increases other elements' effectiveness for their particular purposes. This has been proved, times beyond record, in the laboratory, foundry, factory and under every manner of punishing service conditions. Greater strength, toughness, shock resistance, less temper embrittlement, easier machinability, and many other improvements are present in Moly steels and irons. Yet, while bettering the product, Moly seldom adds to the ultimate costs — and usually reduces them.

To engineers, metallurgists and production executives we offer these interesting books: "Molybdenum in 1934" and "Molybdenum in Cast Iron — 1934 Supplement." Also ask us to mail you our periodical news-sheet, "The Moly Matrix." Be free, too, to enlist our Detroit experimental laboratory's help at any time. Climax Molybdenum Co., 500 Fifth Ave., New York.

MOLY

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INDUSTRY'S MOST MODERN AND VERSATILE ALLOY

THE TEMPERING OF HIGH SPEED STEEL

By Owen W. Ellis
Director of Metallurgical Research
Ontario Research Foundation
Toronto, Canada

A QUESTION THAT MIGHT NATURALLY arise in the minds of both users and makers of high speed steel of the 18% tungsten, 4% chromium, 1% vanadium type is: To what extent do the variations in technique inseparable from ordinary work-shop practice affect the hardness of high speed steel that has presumably been subjected to a specified quenching treatment?

With the view of answering this question the author, some time ago, persuaded a number of members of the Ontario Chapter, American Society for Metals, to cooperate with him in the investigation described below, the results of which are discussed in some detail.

A bar of high speed steel of a well-known brand, 1½ in. wide and $\frac{7}{16}$ in. thick, was cut into eight samples, each approximately 8 in. long. These eight samples were slotted to a depth of approximately ⅜ in., the slots being approximately an inch apart. Each of the eight bars were thus divided into eight sections which, subsequent to hardening, could be broken off if and when desired. The appearance of the slotted 8-in. bar was somewhat similar to that of a 5¢ chocolate bar, which can be so readily broken off, subsequent to purchase, into pieces of a size convenient for mastication and delectation.

The object of cutting the original bar into 8-in. pieces was to distribute them, after slotting, to the different members of the group, it being presumed that by this means a guarantee would be obtained that the eight 1-in. sections of each piece would be subjected to almost identical quenching treatment. It was borne in mind that there might be variations in temperature throughout the bar at the time of quenching, but it was felt that it was far more satisfactory to be sure that the bar had been treated as a whole than to deliver eight small slugs to each member of the cooperating group, these small pieces possibly being treated later one at a time.

In the following discussion of the experiments the various workers have been given numbers, so that their identity has been lost completely, so far as the world at large is concerned. Since the experiments were completed, the various members of the group have been notified of the numbers that were applied to their pieces, but, apart from the author, no one has information regarding the origin of the various samples tested.

(Here it is proper to express appreciation for the help given in this work by the eight members of the Ontario Chapter of the Society, who undertook the preparation of the samples: Messrs. Charles Taylor, J. W. McBean, Don. Fraser, Chester B. Hamilton, N. P. Petersen, W. O. Oliver, W. J. Blair, and H. Smart. To Desmond Hunter, of the Ontario Research Foundation, credit must be given for his care in drawing the samples and testing for hardness.)

As to the treatments that were accorded the samples, it was requested that they be dealt with in accordance with the following recommended practice of the Society:

A. Heat slowly and uniformly in a preheating furnace to a temperature of 1350° F.

B. Transfer to a high temperature furnace maintained at

2350° F., and hold at that temperature for 3 min.

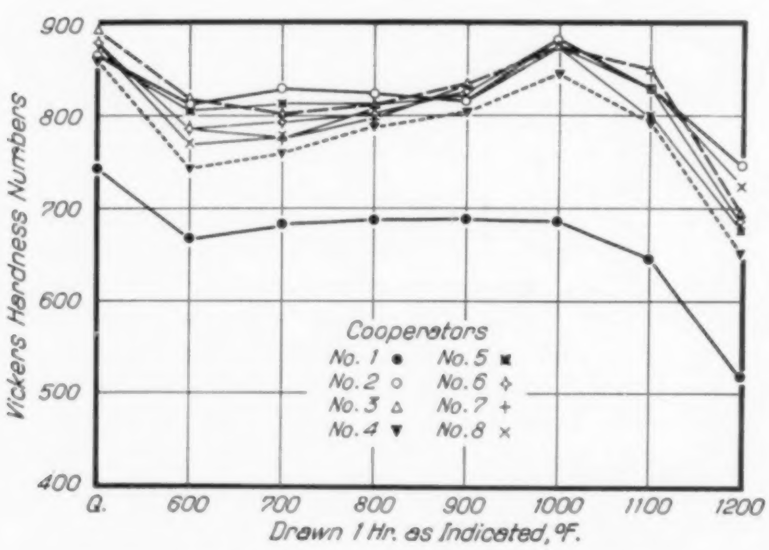
C. Quench the steel in oil, making a note of the temperature of the oil used.

At the same time, information was required of the group regarding the type of furnace in which the work was conducted.

Cooperator No. 1 heated his notched bar to 1350° F. in an open gas furnace and subsequently transferred his sample to another open gas furnace at 2350° F. After 3 min. he quenched the bar in oil at 76° F. Reference to the results of the subsequent tests made on this sample will indicate that, despite his belief that he had fulfilled requirements exactly, he failed to quench from a temperature sufficiently high to give the hardness requisite in high speed tools for satisfactory service. It is of interest to record that all the sections in his sample were cracked.

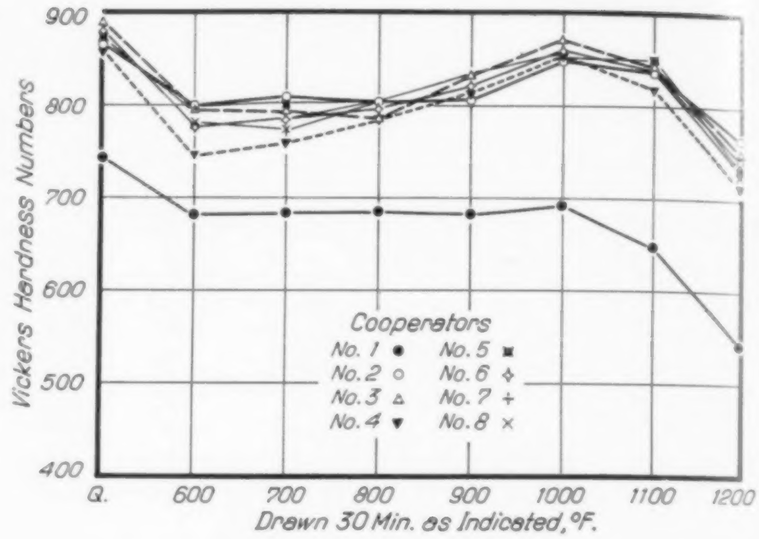
Member No. 2 preheated his sample in an electric furnace at 1350° F. and then transferred it to a semi-muffle gas furnace held at 2350° F. He quenched his piece in oil at 82.5° F.

Number 3 did both his treatments in a gas furnace of the semi-muffle type and quenched his sample in oil at 68° F. Reference to the curves



Duplication of Results to a Striking Degree Is Possible if Steel Is Drawn at Temperature for Maximum Secondary Hardness, That Is, 1000° F. (or Perhaps Slightly Higher)

given herewith will show that he obtained the highest hardness of all. All the sections in his sample, however, were *badly* cracked, and it is suspected that he exceeded the quenching tem-



Hardness Versus Drawing Temperature for a 18-4-1 High Speed Steel Quenched According to Standard Practice in Eight Different Shops, and Drawn 30 Min.

perature laid down in the recommended practice for heat treatment. Note may also be taken of the relatively low temperature of the oil in which he quenched his sample.

Cooperator No. 4 did both his treatments in a gas furnace of the semi-muffle type, quenching his sample in oil at 78° F. He notified the author that he was uncertain whether his sample had reached the 2350° F. specified in the recommended practice. That his surmise was probably correct finds some support in the results of the subsequent tests, as recorded on the curves.

Cooperator No. 5 carried out both his treatments in a gas furnace of the muffle type and quenched his sample in oil at 80° F.

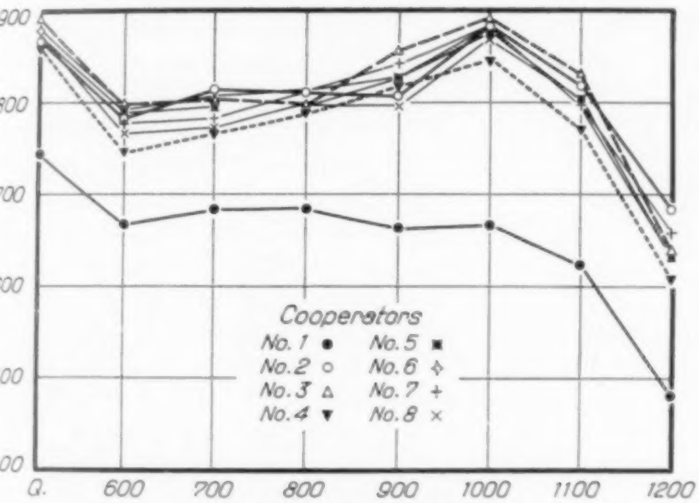
Number 6 did both his treatments in an oil fired muffle furnace, quenching his sample in oil at a temperature of 97° F.

Cooperator No. 7 used a gas muffle furnace for both his treatments and oil at 80° F., while No. 8, last but not least, exceeded the requirements of the recommended practice by heating his sample in an electric furnace to 750° F., transferring it thence to a semi-muffle oil furnace at 1350° F., and finally placing it in a semi-muffle gas furnace at 2350° F. He quenched his sample in oil at 150° F.

Subsequent to the above quenching treatments the eight notched samples were returned to the laboratories of the Ontario Research Foundation for drawing at a series of temperatures varying between 600 and 1200° F. On

their receipt each of the samples were broken at the notches into the eight pieces required for the further experiments, these being grouped in sets of eight, one of each set having been treated as already described.

In the drawing experiments each set of samples were heated for periods of half an hour, one hour, and two hours, respectively, at the specified temperature, and, subsequent to each period of heating, were tested for hardness by means of a Vickers hardness testing machine, using the diamond cone. Eight impressions were made and measured on each of the slugs, subsequent to each of the drawing treatments. The average hardness numbers were calculated from these impressions and were used in preparing the three diagrams which illustrate this paper. (Arithmetical adjustments of the average hardness numbers were of course made in order to enable



Samples in Above Tests, Drawn Two Hours, Appear to Have no Higher Hardness Nor no Better Reproducibility Than When Drawn One Hour

the relative effects of drawing at the various temperatures to be clearly depicted.)

A consideration of these diagrams will make it clear that little, if any, weight can be given to the results which were obtained on the samples supplied by Cooperators 1, 3, and 4. Possible reasons for this have already been noted and need not be dealt with again.

If consideration be given to the results of the tests made on the samples supplied by heat treaters No. 2, 5, 6, 7, and 8, it will be noted that, despite the variations in initial hardness and in the technique which must naturally characterize heat treatment in commercial practice, the hardness obtained as a result of drawing the samples at 1000° F. is remarkably uniform, and this is true of either the half-hour, hour or two-hour drawing periods.

It is somewhat unfortunate that a choice was not made of drawing temperatures intermediate between 1000 and 1100° F. in view of the fact that there is considerable evidence to show that a drawing temperature of 1050° F. will give a somewhat greater hardness than that obtained after drawing at 1000° F. There seems to be no reason, however, why one should expect any greater variation in hardness subsequent to drawing at 1050° F. than at 1000° F.

Low Temperature Draws

Another point of considerable importance brought out by the diagrams is that there is quite a marked variation in the hardness of the samples subsequent to drawing at temperatures both below and above 1000° F. If, for example, one considers the results of the half-hour treatments shown on the curves, one finds that a very wide variation in hardness obtains in the samples subsequent to a tempering treatment at, say, 700° F. The same remarks might be made regarding the longer treatments at this temperature. This point may be of considerable importance in certain circumstances. Low temperature draws have been recommended as likely to conduce to greater toughness in high speed steel, and the evidence in support of this view is very convincing. Present results, however, lead to the view that wide variations in mechanical properties can be expected to result from treatments made at temperatures between, shall we say, 600 and 900° F. There seems room for further work in this connection with the view of establishing the facts, whether or not uniformity of mechanical properties can be obtained at the lower drawing temperatures.

One naturally asks for an explanation of the uniformity of hardness which obtains subsequent to draws at 1000° F. The author believes that this uniformity in hardness is due to the fact that such a heat treatment causes almost complete precipitation of dissolved carbide. At lower drawing temperatures the amount of carbide precipitated may vary quite considerably from sample to sample with time, and variations in hardness (and, one may presume, in other properties also) may be expected as a result of such differences in the microstructural condition of the steel.

THE FIRST ALLOY STEEL

Made by

Michael Faraday

Metallurgist

In sending these photographs of the deal box and the 79 specimens of steel and alloys made by Faraday during the years 1819 to 1824, Sir Robert Hadfield writes:

"It was by a happy combination of circumstances that I was fortunate enough to secure permission to examine these specimens. I had seen a few specimens in the Science Museum, and as an exhibition was to be held during the Faraday Centenary Celebration, I suggested that it would be appropriate to have them examined and analyzed. Sir William Bragg, director of the Laboratory of the Royal Institution (where Faraday had worked for some 54 years) turned over to me the wooden box in which Faraday himself had placed this remarkable collection of alloy steels. Moreover, fortunately he had labelled the box in his own handwriting so there could be no doubt about them.

"The results of the examination made by my energetic staff are contained in my book, Faraday and His Metallurgical Researches. It becomes clear that Faraday may be justly termed the Pioneer of Alloy Steels, as he is called the Father of the Electrical Industry. Although many have been kind enough to associate my name with the inception of modern alloy steels through the discovery of manganese steel and silicon steel, yet I willingly bow to him.

"Adverse or slighting comments on Faraday's work can only be attributed to the argument that because Faraday's steel alloys were not to a large extent used industrially they were therefore a failure. Those who argued thus failed entirely to see the enormous importance of this early research work by Faraday, and the extent to which he anticipated later workers."

The more interesting samples consist of platinum and rhodium alloys, each containing nearly 50% of the special metal, a palladium steel with half the quantity of that metal, and three samples of steel and platinum welded together in attempts to imitate Damascus steel.

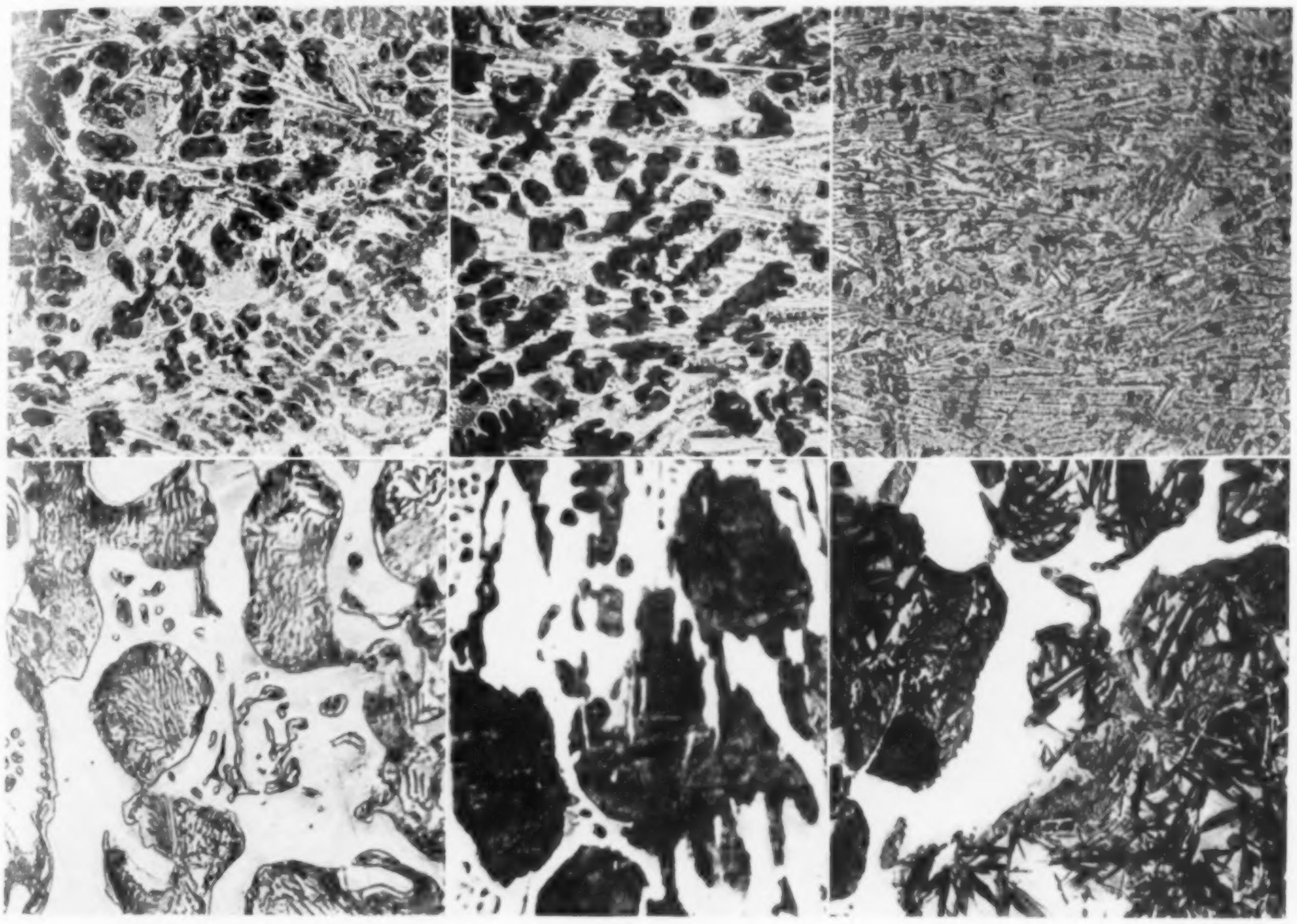
The Box

and

Its Contents

Microstructure of Hard White Cast Iron

All Views in First Row Are 100 ×, in Second Row Are 500 ×



Plain Chilled Iron

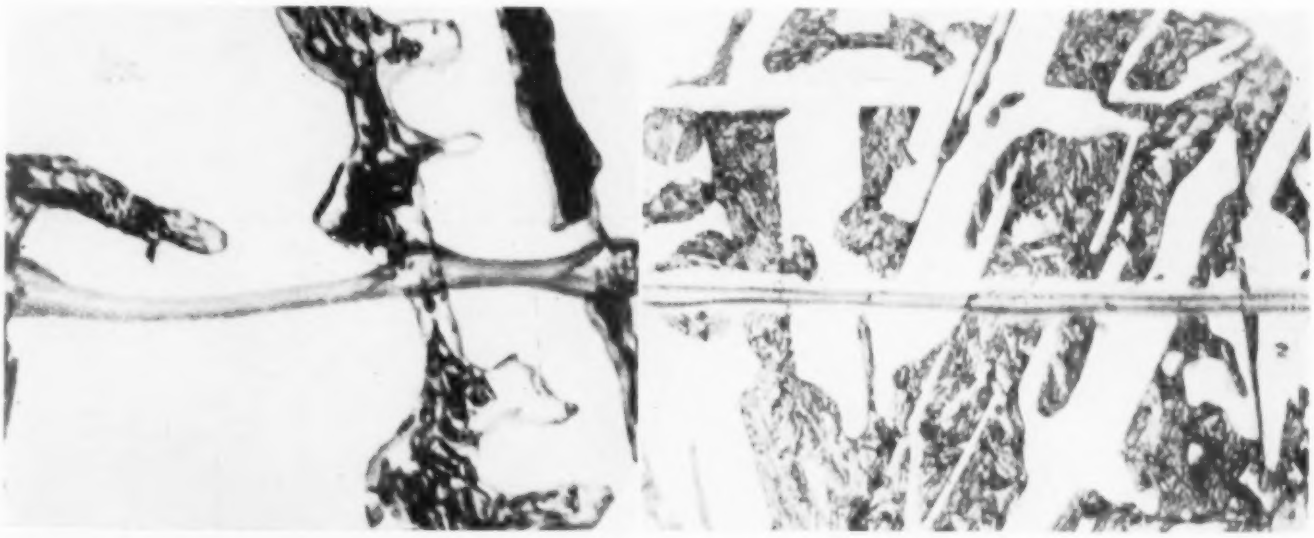
Hardness 400 to 500 Brinell depending on carbon content. Structure at 500 × is shown to be cementite (white) in fine pearlite

Moderately Harder Iron

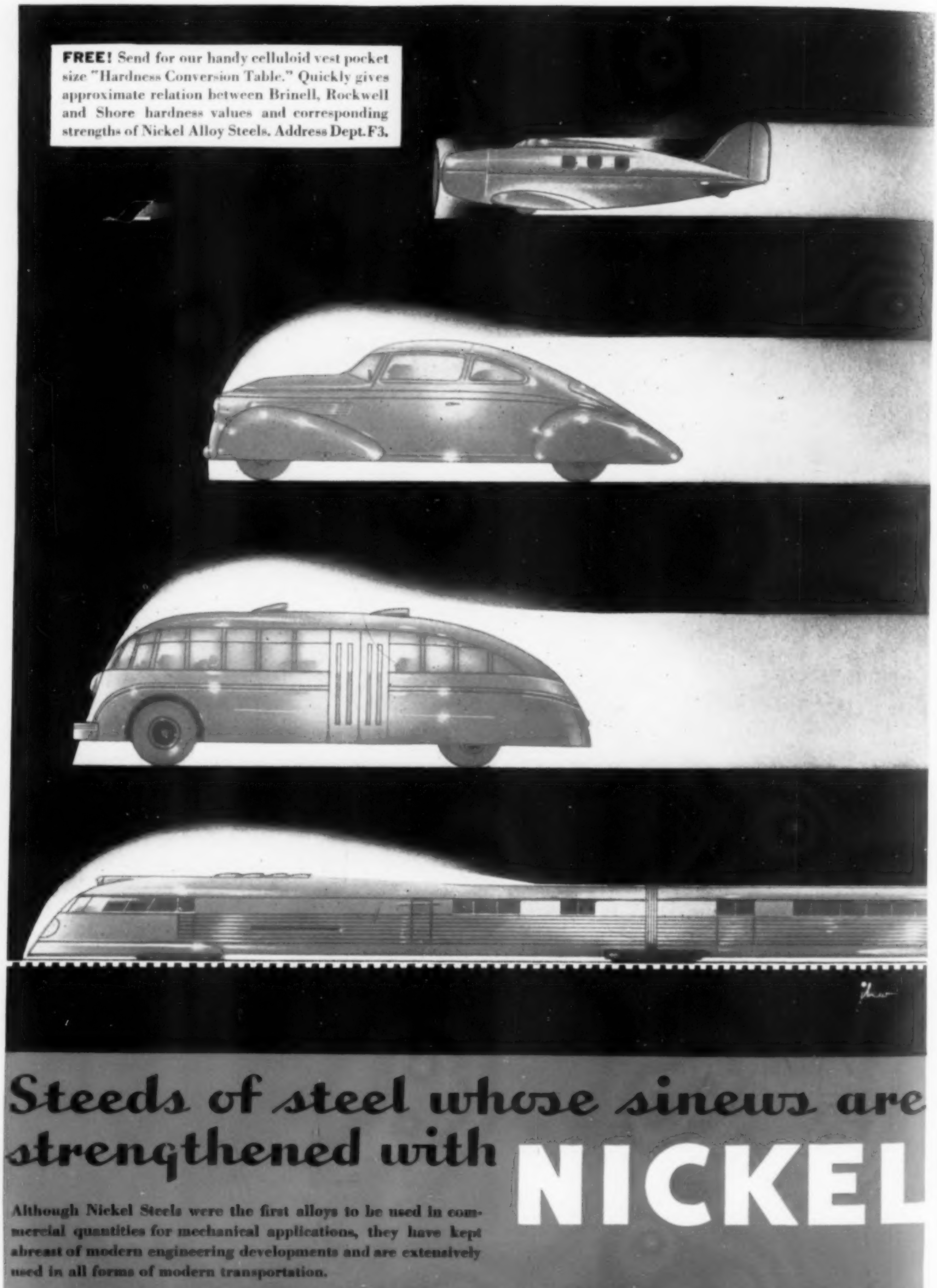
2.5% nickel, 0.80% chromium. Hardness about 600 Brinell. Structure is cementite and sorbite (unresolved)

Fully Hardened Iron

4.5% nickel, 1.50% chromium. Hardness 700 Brinell. Structure is cementite (white) and martensite (needles)



Microcharacter Scratches Show That Pearlite in Plain Chilled Iron (Left) Is Much Softer Than Martensite in Fully Hardened Chilled Nickel-Chromium Cast Iron. All micros Courtesy International Nickel Co.


FREE! Send for our handy celluloid vest pocket size "Hardness Conversion Table." Quickly gives approximate relation between Brinell, Rockwell and Shore hardness values and corresponding strengths of Nickel Alloy Steels. Address Dept. F3.
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Although Nickel Steels were the first alloys to be used in commercial quantities for mechanical applications, they have kept abreast of modern engineering developments and are extensively used in all forms of modern transportation.
THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

QUALITY CONTROL OF BASIC ELECTRIC STEEL

IT IS A RATHER WIDESPREAD IDEA among metallurgists in the consuming industries that the phrase "alloy steel practice" connotes a number of refinements and changes from the methods found satisfactory for the production of soft carbon steels -- tank plate, for instance. This is true insofar as it means that the conscientious manufacturer of alloy steels is carrying on where the traditional practices of the old-time crucible melting shop have failed to meet modern tonnage and even quality requirements. It is true whether the manufacturer uses open-hearth or electric furnaces, and whether the melting units are large, medium or small. In every case he has developed, sometimes by experience, sometimes by logical application of science, a series of practices which enable him to control the quality of his product so it will conform to the pressing requirements of his customers.

Many of these practices are with difficulty transmitted to the printed word. Nevertheless it will probably be useful to outline a number of precautions taken in the melting shop of Timken Steel & Tube Co., for this department has an annual capacity of 180,000 tons of basic electric steel ingots, and its practices have been developed alongside and in competition with a good sized battery of basic open-hearth steel furnaces. Some of the items listed below will be elementary to many metallurgists; they, however, have been included because they are themselves of fundamental importance and are required to round out the complete picture.

By R. P. Brown
Timken Steel & Tube Co.
Canton, Ohio.

One 10-ton furnace, two of 30-ton capacity, and one capable of melting a heat of 100 tons of

Repairing Bottom on 25-Ton Electric Furnace

steel, all of the Heroult type, comprise the Timken installation. These furnaces all operate on 3-phase 60-cycle alternating current, drawing power from three taps — low, medium, and high power — and voltages ranging from 100 to 250. Further adjustments can be made for each power tap by a hand controlled rheostat.

Each furnace has its own transformer, control board and auxiliaries complete. Automatic controls are provided to maintain a uniform length of arc from each of the electrodes to the bath. As usual this is accomplished by relays which are adjusted for the upper and

lower current limits and connected to a direct current reversing motor to raise and lower the electrode mast. Manual controls are also provided for adjustment during the charging, slagging off, and tapping processes.

A special grade of periclase is used for bottom construction, with particles so graded in size that the maximum density will be secured when the material is placed in position with a mineral bond. Bottoms are tamped into position in the proper contour and fired with the electric arc. Furnace roofs and upper side walls are built of silica brick, bottom side walls of magnesite brick. Construction and furnace operation are both watched to prevent molten silica dripping into the bath and diluting the slag. Chromite refractories are ordinarily avoided due to the possibility of chromium being reduced and alloying with the heat.

Spoon Tests Are Made as Soon as Charge Is Melted and Drillings Sent to Laboratory for Analysis

Quality control requires the careful selection and grading of all raw materials used in the charge. Chemical analyses are made at the Timken plant of all shipments to see that the necessary standard is maintained. Scrap must all be low in phosphorus and sulphur, and is carefully graded for composition and physical condition. Limestone must likewise be practically free from sulphur and phosphorus, and for best results the size and physical condition of the lumps must be uniform. Similarly, best results are secured when the graphite or carbon used in the charge is crushed to standard size.

It is equally important that raw materials for slag making be controlled; chemical analyses of all these are made as part of the routine. It is particularly important that the materials be *dry*, as hydrogen from the decomposition of water vapor may be absorbed by the bath with harmful effects later. Special precautions are therefore taken to avoid the entrance of moisture into the furnaces from this or any other source.

An electric furnace charge usually consists of heavy and light scrap, properly proportioned, limestone or burned lime, alloys as necessary, and carbon or ore according to the type of steel to be made, whether high carbon or low. Heavy scrap is charged directly under the electrodes and on the bottom. Light scrap is charged around the electrodes and in the center. Limestone or lime may be charged either in the center of the furnace or around the electrodes — but never directly under them, as it would interfere with the formation of the arc. If the arc is broken, the automatic control will lower the electrodes until they bear on the charge, and they are likely to break and the bath will be contaminated with an excess of carbon. Carbon or ore is usually charged in the center of the furnace.

The heat should melt from the bottom. If the arc is mainly concentrated on the heavy scrap a pool of metal will be formed on the bottom and the lighter scrap will fall in, cooling the bath and thus preventing excessively high temperatures at localized points. Standard practice is to start the furnace at low power and hold it until melting is well under way, after which

medium or high power can be used for the balance of the melt-down period, the current characteristics depending principally on the physical condition of the scrap.

Oxidation of the scrap, surface scale on it, any ore that may have been charged, plus the carbon dioxide given off by the decomposition of the limestone provide oxygen for removal of silicon, phosphorus, manganese, and carbon from the metal during the melt-down period. Some sulphur is oxidized to sulphur dioxide at this stage and escapes to the furnace atmosphere. If limestone has been used in the charge, the lime formed by its decomposition rises through the bath to form a lime-silica slag with the oxides formed from the scrap (silica, phosphorus pentoxide, manganese oxide, and ferrous oxide), together with such magnesium oxide as may be eroded from the bottom, and with other mineralogical oxides from the stone and ore which were charged.

As soon as a heat is melted, spoon tests are taken for chemical analysis. The temperature of the metal is checked by means of an optical pyrometer at this time, as temperature determines the rate of elimination of phosphorus, manganese and sulphur. At the same time the melter notes the fluidity and consistency of the steel as it is poured from the spoon. Routine procedure calls for a determination of carbon, manganese, phosphorus, sulphur, and residual alloys by chemical analysis. The slug is cooled immediately after pouring, drilled, and the chips sent to the chemical laboratory by a pneumatic carrier. This analysis normally takes about 25 min. and is reported back to the melt shop by telautograph to save time and avoid verbal misunderstandings.

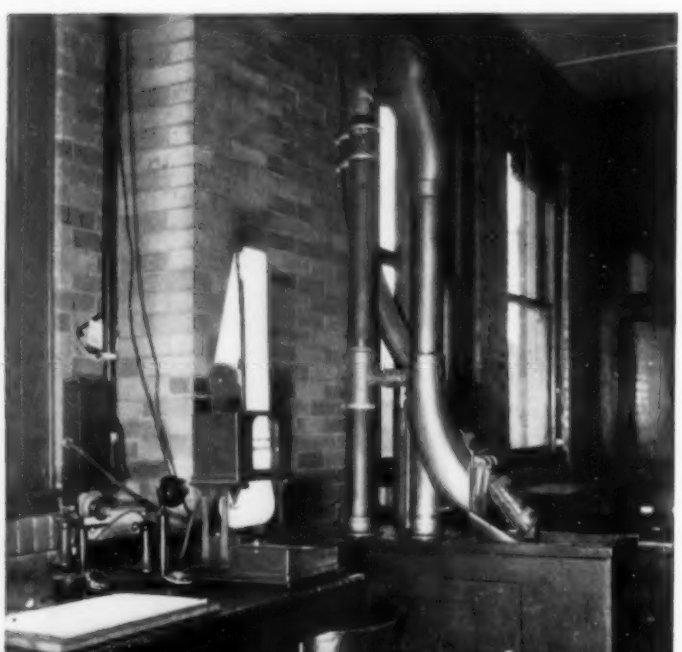
Constitution of Melt-Down Slags

Following this first spoon test, the slag is shaped up by the addition of limestone or burned lime, which increases its basicity; ordinarily no fluorspar is needed. If the chemical analysis of the metal shows too much phosphorus, manganese or carbon, more oxidation is required in the

Slagging Off Through Charge Doors in Timken 100-Ton Electric Furnace. Note electrode masts and arms from each side, operating six electrodes in two three-phase circuits

bath, and mill scale or hematite ore is added to the slag in carefully measured amounts. After the ore has worked through the bath, and the slag is in shape, another spoon test is taken and the analysis of the bath is again checked by the laboratory. When the proper analysis has been reached and the temperature of the steel is correct, the oxidizing slag is removed from the furnace by tilting the furnace slightly and skimming through the charging door.

A typical melt-down or oxidizing slag, when complete and ready for removal, analyzes as follows: CaO 48.7%, SiO_2 19.3, FeO 12.8, Fe_2O_3 3.25, MnO 6.50, MgO 7.10, P_2O_5 0.34, Al_2O_3 1.50, Cr_2O_3 0.30, and S 0.19%. Petrographic analysis shows these oxides to be combined in cooled slag as follows: β di-calcium silicate ($2CaO \cdot SiO_2$), a solid solution phase consisting of magnesium oxide, ferrous oxide, and manganese oxides (MgO, FeO, MnO), undissolved magnesium oxide (MgO), magnetite (Fe_3O_4), and in some cases di-calcium ferrite ($2CaO \cdot Fe_2O_3$) and free lime (CaO). The phosphoric acid is probably combined with lime as tri-calcium phosphate ($3CaO \cdot P_2O_5$) and held in solid solution in the di-calcium silicate ($2CaO \cdot SiO_2$).



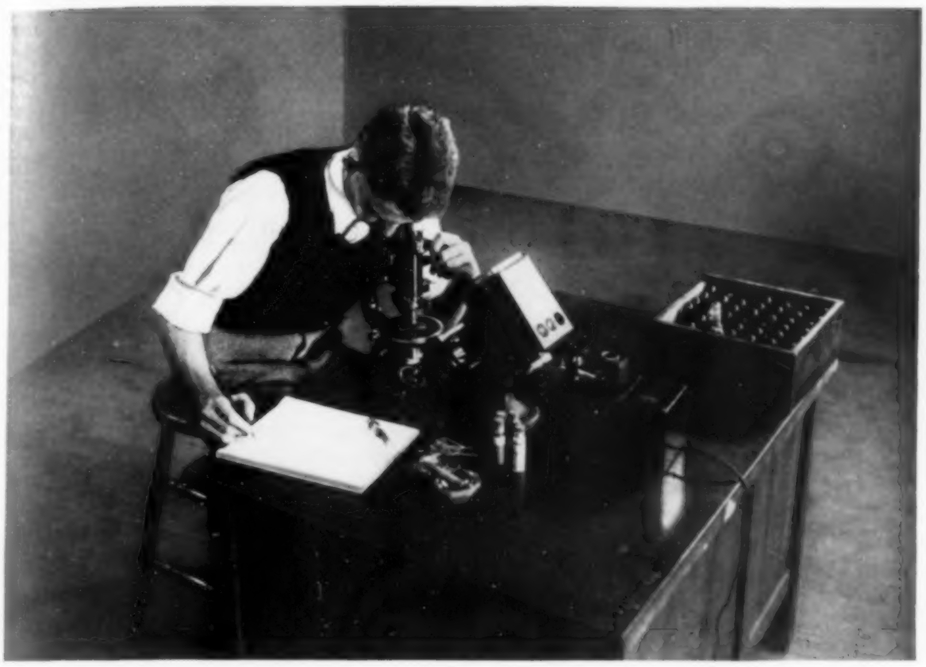
Pneumatic Tube System Connects Furnace Departments and Chemical Laboratory for Rapid Transfer of Samples. Telautographs in all offices transmit analytical data instantly without chance of verbal misunderstanding

To eliminate the human element to as great an extent as possible, all slag making materials are weighed and premixed in advance. In this way, both the proper composition and volume of slag may be consistently secured, and a higher quality and more uniform steel will be produced. (It is a truism that the steel melter makes slags rather than refines steel; the latter is a consequence of the former.) The reducing slag is made up of lime, sand, and fluorspar, coke or crushed electrode being spread over the slag as it is formed to maintain a reducing condition. This produces an atmosphere of carbon monoxide and at the same time calcium carbide is formed in the slag, which, being highly basic, eliminates sulphur from the bath. Usually low power is used during the reducing period of the heat, temperature being controlled by rheostat adjustments.

At this stage part of the deoxidizing materials and alloys may be added to the bath. If a highly deoxidized melt is desired, manganese, silicon, or aluminum will reduce the oxygen content to the desired point. The temperature of the bath and the length of time it will remain under the reducing slag determine to a large degree how alloy additions shall be made; consequently standards have been set at the Timken plant to cover time and temperature conditions as they affect addition of various alloys and deoxidizers. This has systematized melting practice and enables the melter to duplicate uniformly high quality heats. Alloys such as ferrochrome, which have a high melting point, require a considerable length of time for solution and diffusion; it is therefore advantageous to preheat these alloys before adding them to the bath.

Constant attention must be given to temperature control in electric furnace steel production, for the equilibrium between oxygen in the bath and in the slag changes materially with temperature. While it is true that actual physico-chemical equilibrium is never attained due to lack of time, it is obvious that certain desired conditions which are approaching stability at say 3000° F. would be highly unstable and changing rapidly at 3300° F., and would have to be "caught on the run," so to speak.

Hydrogen is also more likely to be absorbed at high temperatures, and that is particularly serious when certain of the chromium-nickel steels are being melted, especially those containing considerable silicon. Hydrogen causes poros-



Examination of Slags by Petrographic Microscope Identifies the Minerals Present and Supplements Chemical Analysis to Give a Better Idea of Actual Furnace Conditions and the Origin of Nonmetallic Inclusions in the Steel

ity in the tops of the ingots, and cracks or flakes in the finished product. Consequently, every effort is made at the Timken plant to eliminate sources of hydrogen such as moisture in the raw materials or water leaks in the furnace, and sufficient carbon is added to the reducing slag to establish an atmosphere of carbon monoxide in the furnace so as to prevent the entrance of atmospheric air, more or less humid.

Spoon tests of both the slag and steel are made at regular intervals during this stage, while refining the heat. Temperature readings are taken with an optical pyrometer and records kept. Viscosity and consistency of the slag is watched closely. Color and appearance are a good gage as to the deoxidizing value of the slag, odor indicates the presence of calcium carbide, and disintegration on cooling indicates that a major portion of γ di-calcium silicate is present.

Even though everything has been calculated in advance, the experience of a skilled melter is, of course, essential to the production of high quality steel, and his judgment must necessarily be relied upon to a large extent during the finishing stages, particularly with regard to temperature control. Lime, fluorspar, and coke are added as required to hold the slag at the proper composition and viscosity and to maintain the desired degree of deoxidation; the exact times and amounts will be decided by the melter.

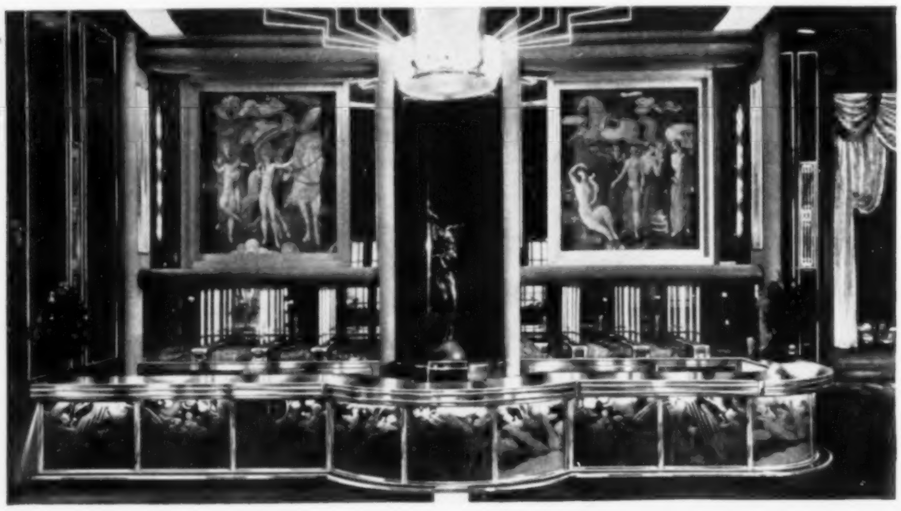
As a matter of record and to enable melters to check their judgment, iron oxide analyses are run on all tap slags. This is of particular importance, as the control of the deoxidizing power of the slag has a vital relation to the quality and physical properties of the finished steel. For example, grain size, abnormality, hardenability, toughness, and distribution of non-metallic inclusions all are related to the oxygen content of the steel and of the slag.

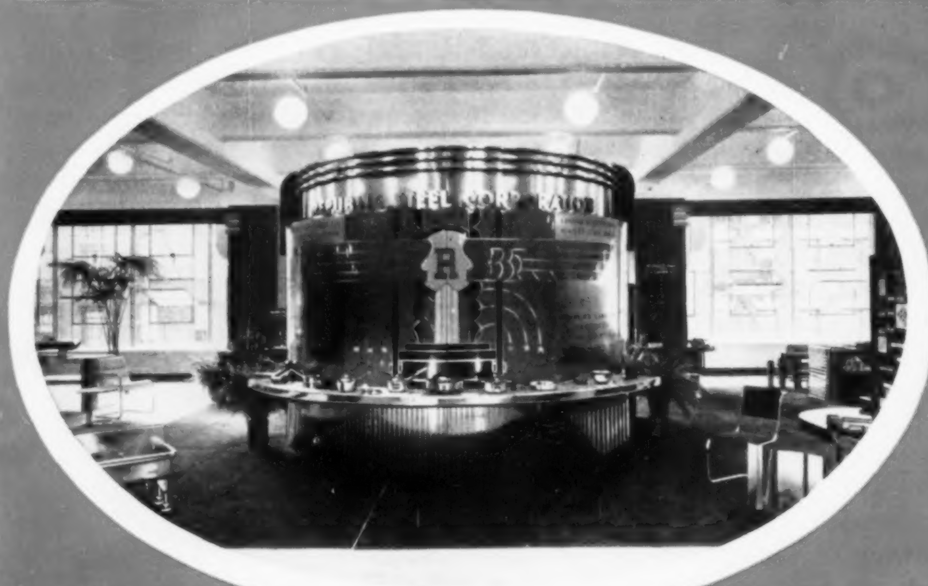
Standard practice calls for a complete chemical analysis to be run on every electric furnace heat from 30 to 60 min. before tapping, results being reported by telautograph. This method gives the melters an opportunity to finish their alloy additions and deoxidation and bring the heat to the desired chemical analysis. Certain physical properties such as grain size can be consistently secured only when deoxidation of the slag is controlled in conjunction with the other factors mentioned. In addition, the practice of adding the bulk of the alloying and deoxidizing elements in the furnace rather than in the ladle allows sufficient time for the oxides formed to rise to the slag and thus hold nonmetallic inclusions in the finished steel to a minimum.

In general, the carbide type of slag is used for finishing Timken steels, but certain low carbon steels require the use of silicon instead of carbon to keep the slag in a reduced condition. In a few other cases lime-alumina type slags are used. Slag practice is always adjusted according to the type and characteristics desired in the steel under production.

Chemical analysis of a typical carbide slag will show CaO 61.5%, SiO_2 24.5, C 0.67, CaC_2 3.54, CaF_2 1.80, FeO 0.43, Fe_2O_3 nil, MnO 0.09, MgO 4.34, Al_2O_3 2.76 and S 0.41. Petrographic analysis of such a slag indicates the presence of γ di-calcium silicate ($2CaO \cdot SiO_2$) and usually tri-calcium silicate ($3CaO \cdot SiO_2$), a small amount of solid solution phase consisting of magnesium oxide, manganese oxide and ferrous oxide (MgO, MnO, FeO), undissolved *(Continued on page 96)*

Welcome to Chicago.





Shimmering panels and gleaming railings of ENDURO Stainless Steel lend a touch of beauty to the huge arena of the International Live Stock Amphitheatre. In the ducts of the Amphitheatre's ventilating system, are sixty tons of rust-resisting Toncan Copper Molybdenum Iron.

(Continued from page 93) magnesium oxide (MgO), and possibly some free lime (CaO). Calcium carbide (CaC_2) is known to be present by chemical analysis although it cannot be seen under the microscope.

Just prior to tapping an electric furnace, temperature readings should be taken and the metal and slag examined. Care must be exercised at this time to see that the runners and ladles are clean and in good condition so as to avoid possible non-metallic inclusions from this source. Additional temperature readings are taken on the stream of metal during tapping.

To allow stirred-in non-metallic inclusions to rise, the ladle stands for some time after tapping is complete and until the temperature proper for teeming has been reached. The final precaution in the production of high quality ingots lies in the design and preparation of the ingot molds and in the cooling. An enormous amount of work and study has been given to these points by steel makers the world over, and cannot even be summarized here. The mold wash (about which little information is available in the literature) must be of such a character as to produce a tough skin on the ingots, but not give off gases which might cause defects.

Advantages of Electric Melting

If mental comparisons have been made as this article is read, the reader will recognize at once a number of items which sharply differentiate good electric furnace practice from good open-hearth practice. For the most part the limitations on the latter are imposed by the construction of the furnace and its mode of heating.

The consistently high degree of uniformity which quality control has made possible in basic electric furnace steel has been one of the fundamental reasons for the preference which has developed for this product. Many factors contribute to this. Flexibility in operation of an electric furnace permits the use of two or even more slags of quite different types during a heat. Temperature can be closely controlled over a much higher range. Alloys can be added in the furnace without undue loss in the slag, and sufficient time allowed for their complete solution — good distribution being secured by the circulation of the metal in the bath. Furnace atmosphere can be easily and definitely controlled, and is not dependent on the combustion of oil or gas. Further, the melter can control the velocity of the stream of hot metal during tapping.

Steel is melted in the arc type electric furnace by the high temperature developed under the electrodes rather than by convection and radiation from a flame as in the case of open-hearth furnaces. Consequently, a higher bath temperature can be used without endangering the roof. The use of these higher temperatures increases the range of slag compositions, and the extent to which refining reactions may be driven; furthermore the slags may vary from medium acid to extremely basic, and still be fluid enough to perform their chemical functions.

Carbon, manganese, silicon, phosphorus, and some sulphur can be removed from electric furnace steel by oxidation under a lime-silica melt-down slag. This oxidizing slag can be easily removed when the above elements are down to proper figures and replaced by a reducing type of slag which deoxidizes the metal and makes it possible to make additions of oxidizable alloys directly to the furnace. Improved homogeneity in the steel results, particularly in the case of high chromium steels, as ferrochrome must be added to a hot bath, free of oxygen, to which heat is continually being supplied.

Carbon monoxide gas resulting from the oxidation of the electrodes during the melt-down period is effective in maintaining a reducing atmosphere above the slag. Consequently the oxygen content in the melt-down slag can be quite closely controlled, and the correct amount of oxygen added through the addition of oxidizing agents such as scale or ore rather than picking it up from the atmosphere. This is of value in controlling the loss of iron from the bath, regulating the oxidation of undesirable elements, and likewise (and of particular importance under present-day conditions) controlling the state of deoxidation of the bath, which has a direct influence on such properties of the steel as grain size, abnormality, hardenability and toughness.

Only by taking full advantage of chemical and physical control, plus the experience based on an analysis of the results of past heats, can consistently uniform steel be produced of high quality in regard to both chemical analysis and physical properties. Detailed records must be kept of all stages of the heat, raw materials analyzed and proportioned in advance of their use, and the cooperation of the men secured by a careful explanation of the reasons for what may seem to them to be too close control. Neither research nor experience alone is sufficient. Both must be coordinated, and when that is done the resulting steel is worthy of the manufacturer.

And Now **NITRALLOY** Cylinder Barrels for the Latest Series of 750 H. P. WRIGHT CYCLONE ENGINES

Finished nitrided Nitralloy cylinder barrel before being fitted into aluminum cylinder head

Photographs courtesy of the Wright Aeronautical Corporation, Paterson, N. J., and Canton Drop Forging Manufacturing Company, Canton, Ohio

Nitrided Nitralloy cylinder barrel showing forging at left, cylinder barrel after being nitrided for fifty hours and the finished cylinder barrel after machining. At the right, a cylinder barrel showing the stages from billet to finished forging.

DEPENDABILITY and advanced engineering design have long been characteristics of airplane engines built by the Wright Aeronautical Corporation.

And now, where high power and high rotated speed present new problems in the design of heavy duty airplane engines, Wright have found that Nitralloy cylinder barrels considerably increase the life of the engine. As a result, the latest series of 750 h.p. Wright Cyclone Engines are built with Nitralloy cylinder barrels. After heat treating, quenching and normalizing the forging, the Nitralloy cylinder barrel is nitrided for approximately fifty hours to obtain a case of .020 to .030 of an inch and shows a Vickers Brinnell test of approximately 800.

Nitralloy, when nitrided from fifty to seventy hours, produces the hardest known steel surface and offers the latest advance in overcoming wear resistance in the presence of severe operating conditions.

Nitralloy calender rolls for the rubber, textile and paper industries particularly, is another significant addition to the constantly increasing list of applications for Nitralloy which has in many instances succeeded where other efforts have failed.

Any one of the companies licensed by The Nitralloy Corporation will be glad to cooperate with you in supplying additional information on Nitralloy.

The nitriding process and Nitralloy are protected under patents controlled by

THE NITRALLOY CORPORATION

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Presenting*

MO-MAX

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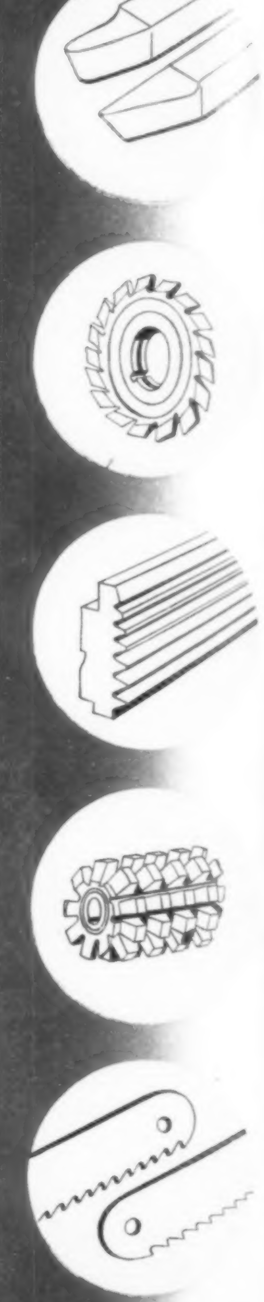
The new high speed steels

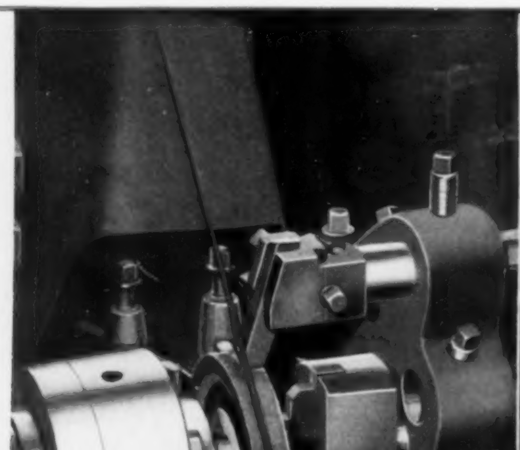
THE executive of any plant interested in reducing the cost of cutting-tools and cutting-operations will welcome the new molybdenum-tungsten high speed steels—MO-MAX. The thin red line that is the hot edge of a cutting-tool receives new support from the hot-hard, strong and tough MO-MAX.

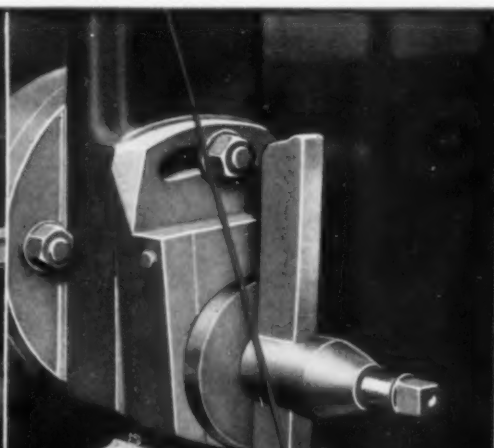
MO-MAX is a standard high speed steel for cutting-tools. Many tool manufacturers have adopted it for their most important products. Numerous tool users specify MO-MAX for their high speed tools.

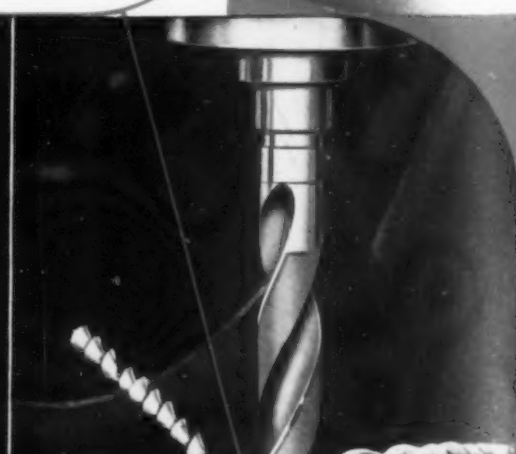
In scores of plants, MO-MAX in the form of twist drills, reamers, cutters, hacksaws, lathe tools, tool bits and other cutting-tools is proving equal to, and often better than, other orthodox steels.

Born of the Great War, when the acute shortage of tungsten made it almost impossible to supply high speed cutting-tools of the then known steels in satisfactory quantity and quality, MO-MAX is the result of many years of painstaking research and experiment.

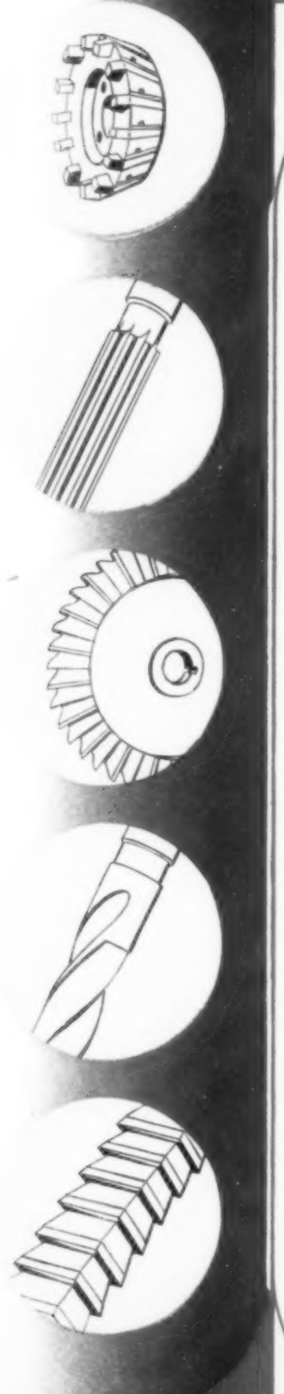








THE THIN RED LINE•

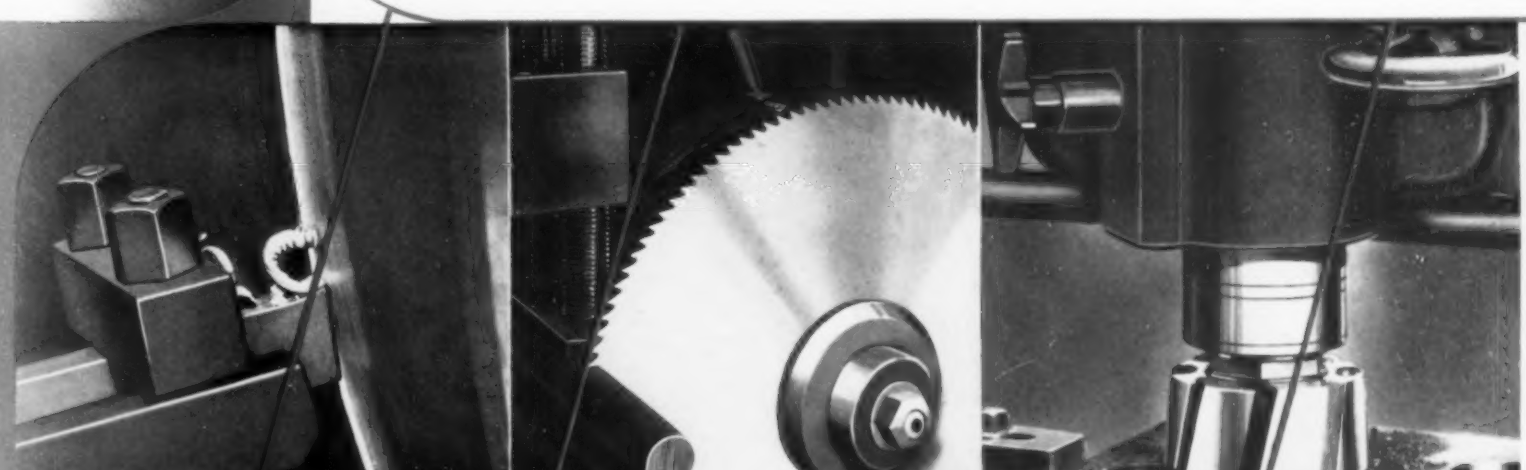


NOW, the results of tests, made under severe conditions of production service, demonstrate that MO-MAX has reached a commanding position in the field of high speed steels. It has shown a marked superiority where toughness and resistance to abrasion are essential.

MO-MAX, in the annealed condition, machines more readily with consequent savings in machining costs. Forging and hardening operations are carried on at temperatures about 150° F lower than required for conventional high speed steels. In addition to the savings due to lower cost in the tool room, MO-MAX is economical because it weighs about 8% less than other high speed steels commonly used.

MO-MAX is independent of foreign sources of tungsten. The United States has ample deposits of molybdenum—the chief alloying element—and American mines can supply the small amount of tungsten needed. Tungsten, therefore, ceases to be a "strategic material" and MO-MAX users are assured a more stable price and supply.

MO-MAX deserves the same careful study, handling and application as did the high speed tool steels that preceded it. For more detailed information about MO-MAX consult your usual sources of supply.



MO-MAX*

TRADE MARK REG. U.S. PAT. OFF.

APPLICATION—All high speed cutting-tools, punches, dies, wear and heat resisting parts.

APPROXIMATE COMPOSITION

C	.60 — .85	Mo	7.75 — 9.25
W	1.25 — 2.00	Cr	3.50 — 4.00
V	.90 — 1.50		

The lower carbons are used for tools requiring great toughness. The higher carbons are used for tools requiring great hardness and especially great red-hardness. The carbon content of MO-MAX is in general about 0.10% higher than for comparable grades of 18-4-1 high speed steel.

WEIGHT—Density about 7.95—approximately 8% less than 18-4-1 high speed steel.

MACHINING—MO-MAX is easy to machine and grind. Its hardness after annealing is slightly less than that of most high speed steels.

HOT WORKING AND HEAT TREATMENT—Typical working temperatures are:

Forging 1900°-2000° F (MO-MAX is workable down to 1700° F)

Annealing 1500°-1550° F

Hardening 2175°-2250° F to be varied according to the carbon content and kind of tool.

Tempering about 1050° F.

HARDNESS—Rockwell hardnesses in excess of C 65 are easily obtainable.

TOUGHNESS—As tough or tougher than other well known high speed steels.

LIFE—Total life and life between grinds is at least equal to that of high speed steels now in general use.

* MO-MAX is a proprietary name owned and controlled by The Cleveland Twist Drill Company and its only licensed use by others is on steel made and sold by licensees under Patent Number 1,937,334.

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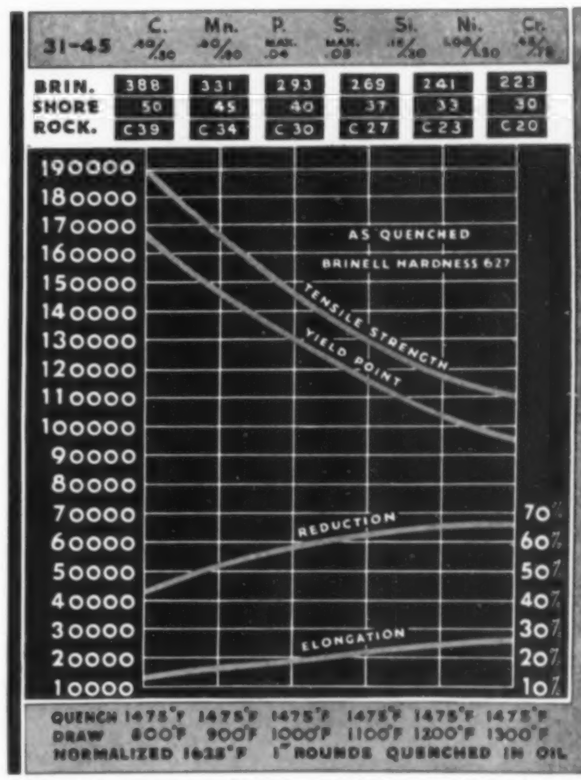
The new high speed steels

SOME NOTES ON BETHLEHEM ALLOY STEELS

IV - Nickel-Chrome Steels



★ *Physical properties of S. A. E. 31-45, one of the "Mayari" type nickel-chrome steels.* ★

Chromium is essentially a hardening element when alloyed with steel. Nickel imparts greater strength and improved ductility. The combination of nickel and chromium produces a steel carrying the benefits of the added strength of both alloys. Chromium is the more effective in increasing the hardness penetration in the heat-treated condition, while ductility is improved by the nickel. Nickel-chrome steels have found wide industrial use, including very important applications in the automotive industry.

The original Bethlehem "Mayari" Steel was a type of steel similar to the present S. A. E. 31xx Series, the alloying elements in which are 1.00 to 1.50 per cent nickel and 0.45 to 0.75 chromium. This steel is produced with carbon contents in the accepted ranges from 0.10 to 0.70.

Like other alloy steels containing up to 0.25 per cent carbon, this type is ordinarily used for carburized parts such as rock-bit cones, stub shafts, pins, worms, gears and pinions of many types, universal joints, rolls, rocker arms, airplane engine cams, studs, bolts and pins, and finds wide application in such service. Up to 0.35 per cent carbon, it is a water-hardening steel; with a carbon content of over 0.35 per cent, it becomes an oil-hardening steel. Typical uses of 31xx nickel-chrome steels with this higher-carbon content are: connecting rods, rods, master rods and straps for airplane engines, compressor crank-shafts, spindles, tool joints, chain-link stock, engine bolts, superheater bolts, steering knuckles, drive shafts, axles, spring clips, propeller shafts, shovels, picks and similar items. In the 0.30 to 0.45 per cent carbon range, the principal applications include bolts, studs, shafting and gears. As the carbon content passes 0.50 per cent, this grade is widely used for die blocks, tool holders, gears and pinions.

The 32xx Series, which contains 1.50 to 2.00 per cent nickel and 0.90 to 1.25 per cent chromium, has an excellent balance of hardening elements which on heat-treatment results in a high combination of strength and ductility. This series is applicable to parts where the service requirements are more severe than can be met with steels of the 31xx Series.

The 33xx Series, a richer alloy than the 32xx Series, contains 3.25 to 3.75 per cent nickel and 1.25 to 1.75 per cent chromium. The 34xx Series carries 2.75 to 3.25 per cent nickel and .60 to .95 per cent chromium. While both of these grades have very definite applications they are not as widely used as steels falling in the 31xx and 32xx Series.

★ *the where of—*

ROLLED STEEL CONSTRUCTION

● "How can we apply rolled steel construction to our own products?" This question is asked with increasing frequency by many manufacturers who recognize the economy and the advantages of rolled steel for machine construction.

What types of machinery lend themselves to the more extensive use of rolled steel? What savings are possible? How is weight affected? What production advantages are possible? What types and forms of steel are best suited? What should we know about buying? What are the opportunities for the use of rolled steel combined with castings?

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Send today for this booklet "Rolled Steel For Machine Construction." It was prepared by practical men . . . engineers and designers. It offers a short cut to a more complete understanding of the manifold advantages of rolled steel. And it includes many suggestions on economy in buying and on modern shop technique. A copy is yours for the asking . . . plus further information and the counsel of our representatives if you want it.

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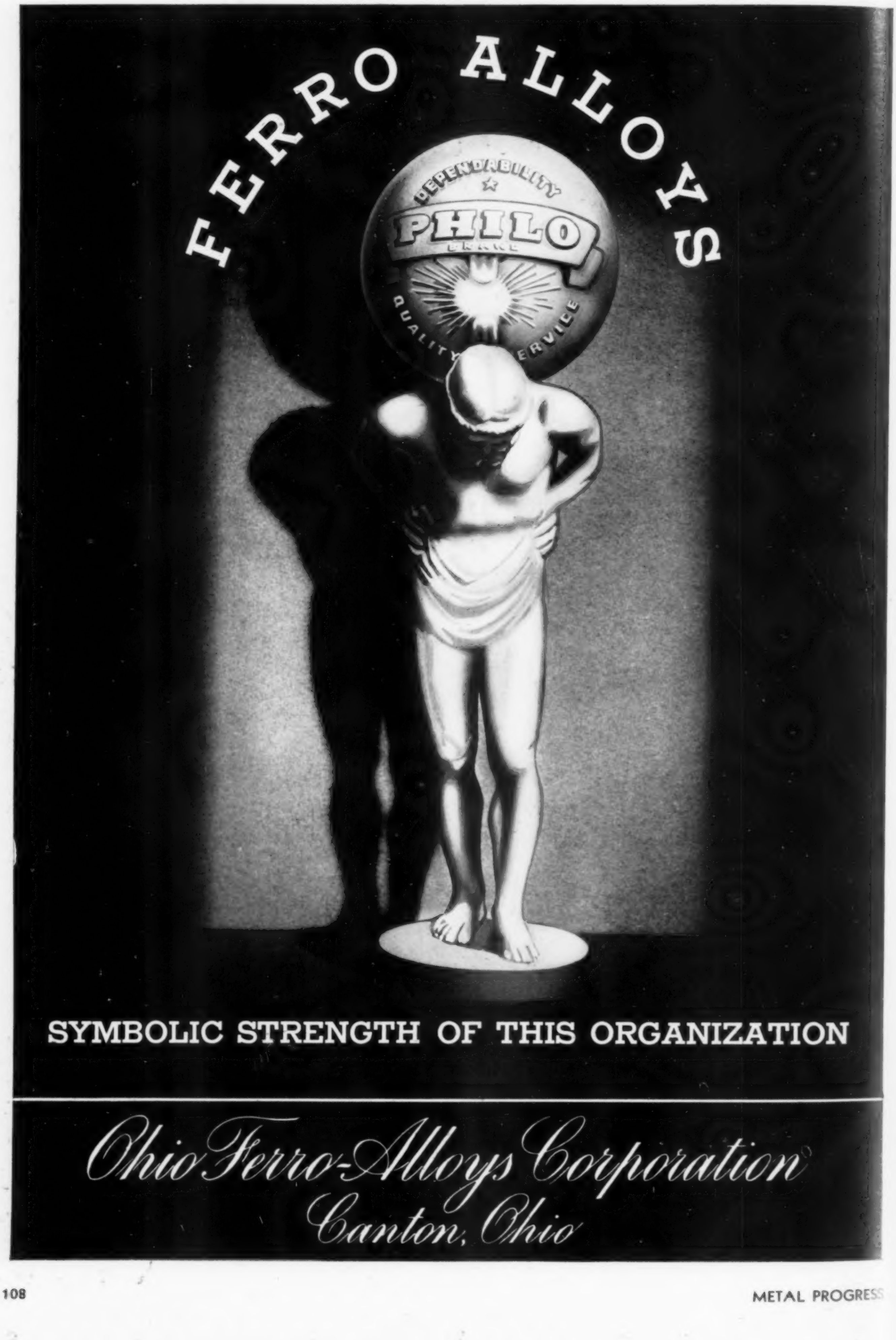

FERRO ALLOYS
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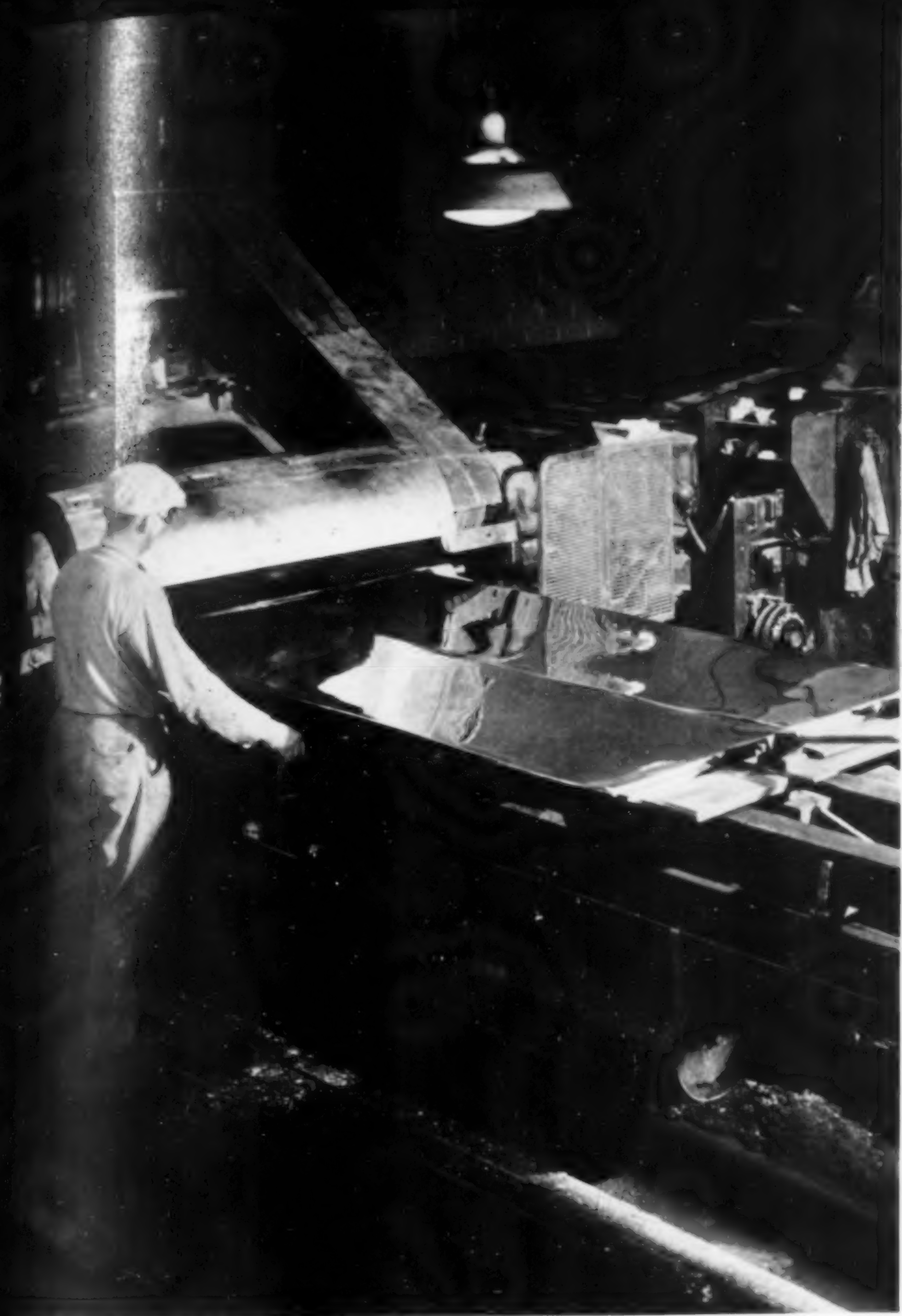
Canton, Ohio



ourtesy Republic Steel Corp.

STAINLESS STEELS

The View Above Shows a Special Buffing Machine Giving the Final Mirror-Like Finish on a Superfine Sheet. . . . Many Fabrication Problems of Importance to Users of This Material Center on the Weldability of the Alloys, a Matter Discussed Briefly in the Following Pages

NOTES ON WELDING IMPORTANT GROUPS OF STAINLESS STEELS

WELDING OF THE HIGH CHROMIUM irons and steels generally classified as "stainless steels" has attracted much attention because of the great diversity of alloys now on the market. A large amount of work has been required to determine the weldability of the alloys, the welding rods or electrodes supposed to be suitable, and the properties of the weld metal and the composite joint. The diagram on the next page shows test plates for such purposes, or for testing the capability of the welding operator for work on materials of known weldability.

Three types of samples are provided for testing the corrodibility of the weld metal and the joint; wedge shaped specimens for salt spray, prisms for acid immersion, and small rods for intergranular susceptibility. The salt spray test, which indicates the resistance to marine atmospheres, subjects the sample for 100 hr. to a fog of salt water (4% sea salt). Chemical corrosion is indicated by the weight loss during five 48-hr. periods (boiling in 65% nitric acid in a reflux condenser). Intergranular corrosion is estimated by the change in electrical conductivity after boiling the rod in acidified copper sulphate (47 c.c. H_2SO_4 and 13 grams $CuSO_4 \cdot 5H_2O$ per liter). While none of these tests is formally standardized, test figures derived as above would be accepted by most metallurgists as sufficiently informative to supplement others simulating service conditions.

It would seem that more importance should attach to the above tests on welded joints than upon tensile and ductility tests, for, after all, the expensive corrosion resisting and heat resisting steels are used primarily to resist corrosion and heat, and the method of fabrication must not interfere with this aim. Consequently, tensile and bend tests may be used to prove *soundness* at the joint rather than high strength. Porosity is especially dangerous in many otherwise harmless solutions, because a cavity, once penetrated, offers a good harbor for an oxygen concentration cell, leading to rapid penetration by the pitting type of corrosion. Hence the widespread practice of making X-ray films of all important structures and castings for the petroleum, chemical, and power industries.

All the important welding processes are being used and to limit this discussion to reasonable bounds, notes will only be given on the most important and frequently met applications.

Cleanliness of the parts being welded is quite essential, since any oil or grease will carburize the weld, and dirt will form damaging inclusions. The thermal conductivity of the stainless steels is only one-half to one-third that of mild steel; this tends to localize the heat effect. The thermal expansion of the chromium-nickel alloys is almost half as large again as that of mild steel; more than usual provision must therefore be made to minimize warping or internal strains.

It is, of course, poor economy to scant attention to the preliminary set-up and assembly of items made of these expensive alloys.

Welding thin sheet with a flame (either oxy-acetylene or atomic hydrogen) has the same advantage over the arc welding process when working with the

By Ernest E. Thum
Editor, Metal Progress

From a paper contributed to the Symposium on Welding of Iron and Steel by the Iron & Steel Institute

high chromium steels as when fabricating the plain low carbon steels. Edges of thin sheets are preferably bent up to a height of about $\frac{1}{16}$ in., and this standing seam then melted down, as shown in the cut on the next page. Abutting edges may also be welded, adding some metal to the joint with a welding rod; in this case a backing-up strip of copper is helpful.

Two metallurgical considerations must be kept in mind: *(a)* Avoid carburization and *(b)* avoid inclusions of chromium oxide.

As most of the commerical alloys in sheet and strip form have sharply limited carbon contents, the joint should match this composition. The oxy-acetylene flame must therefore be carefully adjusted to "neutral" — one which lends neither carbon nor oxygen to the joint. (In the atomic hydrogen flame carbon is absent; such a method of welding is very suitable.)

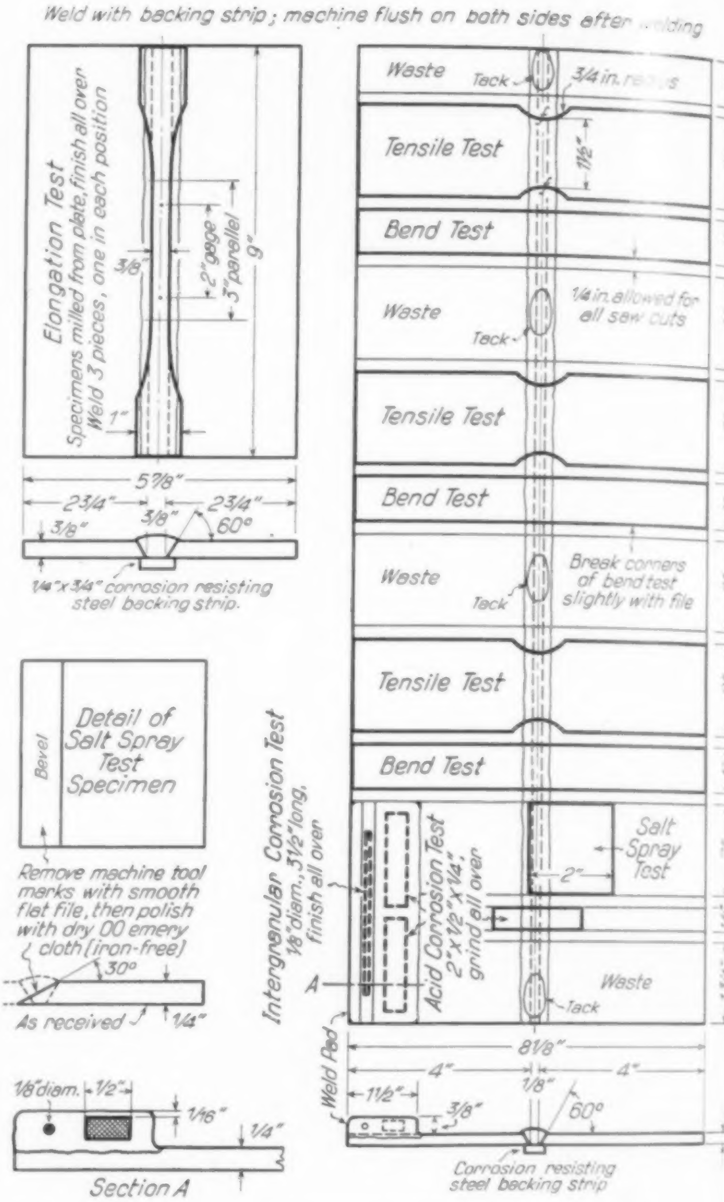
Some "stabilized" alloys are on the market which are less sensitive to the effect of a little extra carbon, and these would be chosen to resist severe corrosion. Other compositions have enough titanium present to carry nearly all the carbon in the carbide of this element, where it acts as an inert inclusion. Lastly, a little extra carbon is of small moment in the chromium-iron alloys containing, say, 15.5% chromium — near the upper limit of definitely hardenable steels. Welded structures of this material for the chemical industry have been heat treated to give good combinations of strength and ductility.

Oxidation of the chromium is also minimized by correct flame adjustment. The oxide that forms is dissolved in a suitable flux, of which there are several on the market. A water-mixed paste is painted on the top and bottom of the joint, and on the welding rod, if any. The seam may also be placed on a slight incline, so that the melted flux will run ahead of the hot spot, and clean the metal.

In welding a standing seam the forward method of welding — working toward the unwelded butt — is preferred. A flame no larger than necessary is essential; rapid work also prevents a boil from too much heat, resulting in a porous weld. Interruption of work, patching, and intersecting seams should be avoided. Flux should be cleaned off *thoroughly*.

Coated Electrodes of Stainless Steel

Metallic arc welding is utilized for most of the fabrications when the thickness of the parts being joined is $\frac{3}{16}$ in. or over. It is characterized



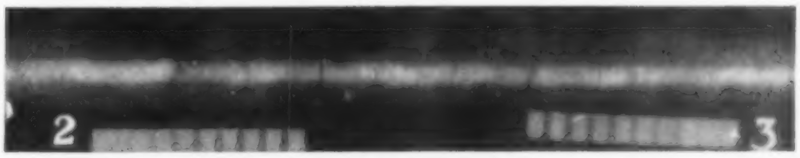
Test Plates Suitable for Determining the Weldability of a New Alloy or New Electrode, or for Estimating the Capability of a Workman. Slightly modified from those used by U. S. Navy, Bureau of Construction and Repair

by a much more localized heat effect; the temperature of the weld in the vicinity of the arc drops to about 1000° F. in about $\frac{1}{4}$ in. This restricts the volume of metal which has been changed by heat treatment, or overstrained by thermal expansion.

The problem of protecting the highly reactive metal in the arc from the atmospheric gases has been solved by the use of covered electrodes. A properly formulated covering has the added function of stabilizing the electron stream in the arc, increasing the welding rate, and promoting soundness.

Few of the coatings are designed to supply much of the alloying elements to the joint; they are primarily protectors; the problem is to transfer metal to the joint without change. Com-

pounds containing carbon are excluded for obvious reasons; even so, carbon will increase about 0.05%. Some strong deoxidizers are also incorporated, such as ferromanganese, ferrotitanium, or aluminum. A fusible protective slag is provided by such substances as lime, silica, clay, cryolite, and the binder (sodium silicate solution). The ingredients are usually mixed with the minimum of water, applied to the cleaned wire either by dipping or extrusion, and then carefully dried and baked.



X-Ray Print, Originally 15 In. Long, Showing Numerous Transverse Cracks Across 5% Cr Weld, Due to Lack of Preheat

There are now available satisfactory covered electrodes for the principal types of heat and corrosion resisting alloys. When using them the chromium loss — electrode to joint — should be not more than 1.0 or 1.5%, which is usually compensated for by having a corresponding excess in the wire. Other common elements are practically unchanged. Perhaps two-thirds of the titanium and nearly half the columbium added to the electrodes for stabilizing the austenitic alloys against structural transformation are lost in the transfer.

For Thin Sheet Metal It Is Convenient to Flange the Metal at the Joint, Paint It With Flux, Face the Edges Tightly Together, and Melt Down the Protruding Edges. Butt welds with welding rod are also made

A considerable increase in nitrogen may be found — as much as 0.30% being recorded — but in the chromium-irons (16% chromium and over) nitrogen acts as a strengthener. Its effect in the chromium-nickel steels such as 18-8 is uncertain; fortunately with good coatings the pick-up is small. The parent metal commonly contains from 0.02 to 0.04% of nitrogen; in the weld metal this may be doubled.

The electrodes are somewhat smaller than electrodes for mild steel; $\frac{3}{16}$ in. diameter is the approximate upper limit. Larger electrodes and high currents tend toward porous welds. Direct current welding is usual, with work negative. Since the electrical resistance of these alloys is many times greater than that of medium steel, short electrodes are the rule.

4 to 6% Chromium Steel

A very large amount of seamless tubing containing 4 to 6% chromium, 0.5% molybdenum, 0.15% carbon (max.) is used in pressure stills handling corrosive crude petroleum. Its welding includes joining up pipe, "safe-ending" of tubes, and construction of superheater headers. Stills operate at up to 1000 psi. pressure, and the effluent may be at 930° F.; obviously unsound welds cannot be tolerated in such equipment.

E. S. Dixon, of the refining department of The Texas Co., Port Arthur, Texas, an original sponsor of the low chromium tube, has described welding operations as practiced for construction and repair in Metal Progress last February. The principal precaution is to preheat the joint to 600° F., and at no time should the work cool below 300° F. Immediately after completion the weld should be annealed at 1600° F. and slowly cooled, in order to eliminate the undesirable characteristics which air-hardened chromium steels possess. (This includes both field and shop welds.)

Corrosion tests in actual service have consistently shown that the deposited weld metal is equal to the parent plate in resisting deterioration. Hot oil pump discharge lines with field welded and annealed joints operating under 500 psi. pressure at 800° F. for one year have revealed a very reliable, practical, and dependable joint.

J. C. Hodge of Babcock & Wilcox Co., Barberton, Ohio, has loaned the radiograph at top of this page of a weld in such an air hardening steel con-

taining numerous transverse cracks owing to lack of preheating prior to welding. Practice in his plant was summarized in METAL PROGRESS last April. This article may be consulted for data as to properties of welds after various types of heat treatments.

16% Chromium-Iron Alloys

Since low carbon chromium-iron alloys containing more than about 18% chromium are ferritic alloys and incapable of being refined by heat treatment, the present trend seems to be toward keeping the chromium below that figure, or adding a little nickel, either of which converts the alloy into a pearlitic one, capable of heat treatment. The British "twoscore" alloy — 2% nickel, 20% chromium — is one example; in America the tendency would be to select a lower chromium steel (say, 16%, or even 15% chromium, no nickel) wherever the corrosion resistance would be sufficient.

Considerable chromium-iron, containing 16 to 18% of chromium, 0.10% (max.) of carbon, has been utilized by the chemical industry, notably for nitric acid equipment. Early equipment was riveted, and has performed admirably. However, the largest share of the chemical equipment being constructed today of this alloy is welded — a situation which would not have been tolerated by chemical engineers five years ago.

This change of attitude has come about by a better understanding of the capabilities of the alloys. Toughness of the true chromium-iron (ferritic) alloys is largely a function of the grain size. In the plate this is controlled in the steel mill by proper ingot practice to prevent large primary crystals, and by temperature control in rolling, especially at the last pass. Weld metal of corresponding composition is quite coarse grained, and the transition zone is also coarsened and embrittled no matter what welding rod is used. Fortunately, the alloys on the low side of the specification judged best for nitric acid (16 to 18% chromium) have enough of the characteristics of steel to be considerably benefited by a long anneal, say 4 hr. at 1400° F., followed by slow furnace cooling to about 1100° F., thence air cooled. Higher annealing temperatures should be avoided, else the grain size of the original plate will coarsen.

Welding is done while the alloy is mildly preheated (250° F.). If cooled directly the joints will be extremely brittle. After annealing the toughness is quite sufficient for most services. Parts subjected to impact should preferably have an auxiliary structure to carry the stresses, or be constructed of metal of relatively low chromium content (say 15 to 16%), thus achieving a compromise between toughness and corrosion resistance. Since these alloys lose their brittleness when warm, equipment which operates at moderate temperatures is relatively free from these limitations.

18% Chromium, 8% Nickel Alloy — Problems in connection with the welding of the important austenitic alloy known as 18-8 (carbon under 0.20%, chromium within the range 17 to 20%, and nickel 7 to 10%) largely center around the question of the corrodibility of the joint or its deterioration in service; it presents few difficulties from a welding standpoint.

A close chemical match can be obtained between weld metal and adjoining plate. Leon C. Bibber, senior welding engineer, U. S. Navy Bureau of Construction and Repair, has sent some average results on all-weld-metal tensile specimens, annealed at 1800° F. for 30 min., then air cooled.

In his opinion, 75,000 psi. ultimate strength as welded and 25% elongation should "pass" a welder on a qualification test, and warrant a design on the basis of about 88% joint efficiency in a non-reinforced butt joint. Tests of bars welded in the vertical position are not materially different; overhead welds may be expected to be less ductile and about 10% weaker. All bend specimens from any position should bend to an angle of 180° about a pin which is 2.5 times the thickness of the plate (open side of the V in tension).

Properties of 18-8 Plate and All-Weld-Metal

	18-8 Plate As Rolled	Weld Metal As Welded and Annealed
Ultimate strength	85,000 psi.	71,000 to 78,000 psi.
Proportional limit	18,500 psi.	19,000 to 23,000 psi.
Yield point	42,000 psi.	50,000 to 54,000 psi.
Elongation in 2 in.	59%	18 to 23%
Reduction of area	70%	24 to 30%
Modulus of elasticity	30,000,000	26,500,000
Brinell hardness	129	133 to 137

After heat treatment the welds should be ground smooth and flush. Soundness of the metal at the joint is of the utmost importance. The entire surface to be exposed to corrosion should be pickled or sandblasted to remove all scale, after which it should be passivated for not less than 1 hr. in a 20% nitric acid solution, fol-

lowed by a thorough washing with water to remove all traces of acid. The vessel can then be given any degree of polish desired. In general, high polish is in itself an inhibitor of corrosion, and on many classes of work polishing may replace the pickling and blasting operations described above.

Corrosion at Welds

Some there are who insist that an 18-8 alloy with moderate carbon content (especially with chromium and nickel on the high side) may be welded and placed into many kinds of service with impunity — as for instance, for apparatus handling food stuffs, liquor, and malt, and for atmospheric exposure.

Others believe that the best insurance against eventual trouble is to use metal with the lowest possible carbon content (0.08% max.). If carbon is very low, the tendency to precipitate carbides along the austenitic grain boundaries at temperatures between 800 and 1500° F. is minimized. Even though it is impossible to weld without heating some of the metal to this dangerous range, the time may be short and the above-mentioned effect is therefore checked in the incipient stage, and the probability of penetration even by strong corrosives along grain boundaries is therefore minimized.

Still others believe that damage done by the welding heat can be remedied by heating the structure to some temperature above the dangerous zone, say 1900 or 2000° F., where any precipitated carbides are redissolved in the austenite, and then cooling through the 1500 to 800° range at a speed sufficient to prevent re-precipitation. However, it is difficult to avoid sagging at such high temperatures, and even more difficult to ensure that all parts of it will be cooled at a sufficiently rapid rate.

Finally there are those (and the Editor is one of them) who are confident that where service conditions indicate the possibility of trouble from intergranular corrosion, the best insurance is to use material that is alloyed with titanium and stabilized, i.e., by a moderate amount of cold work followed by a heat treatment at about 1300° F. This deposits titanium carbides throughout the austenitic crystals rather than at the grain boundaries. In using such metal the problem is to deposit weld metal that has the same inherent resistance to damage during prolonged heating at temperatures in the dangerous zone.

Resistance welding is well developed for manufacture of structures and machine parts, and also for thin-walled tubing. The latter has been exploited by Steel & Tubes, Inc., which uses an adaptation of the so-called Gustav Johnson process, described at length in the Sept. 1930 issue of METAL PROGRESS.

The Dining Car Chef Can See His Reflection in the Fittings and Utensils — Stainless Throughout. Courtesy Republic Steel Corp. and Missouri-Kansas-Texas Lines

Resistance Welding of Stainless

Clean strip of accurate width is passed through a series of forming rolls, emerging in the proper tubular section. Passing on, it immediately enters the welder, a very heavy struc-

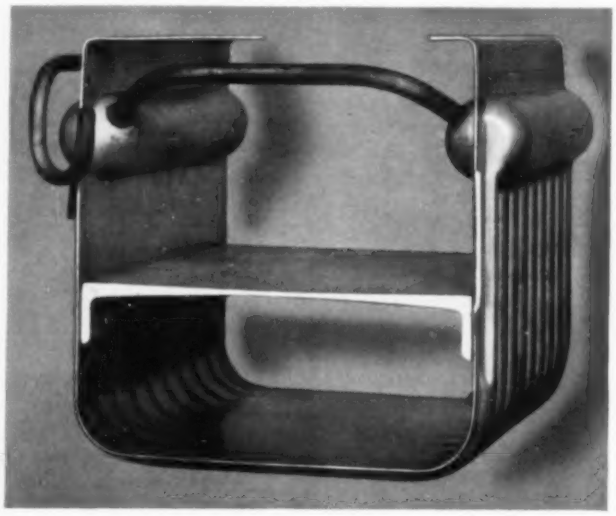
ture resembling a stand of a universal rolling mill. Here it is pinched from each side by suitable rollers. The seam at the very top is straddled by a pair of hardened copper disks set parallel to each other, and these rotate as the tube passes through, always making good electrical contact with the pipe below, and leading in an alternating current of correct voltage and amperage. Simultaneously, the tube is squeezed from the sides so that a combined resistance and pressure weld is formed with a very slight upset both inside and outside. Grain growth along the narrow zone is mitigated by the slight amount of hot work.

This process is very successful with the low carbon, austenitic chromium-nickel alloys, 18-8, 25-12, and 25-20 (the first one especially), the product passing the standardized crushing and expanding tests. While acceptable joints may be made in the 4 to 6% chromium steels, the process has not been adapted to the high chromium steels (12 to 14% Cr) or the chromium-irons (18% Cr and higher).

More conventional resistance welders or "butt welders" are also commonly used for either 18-8 or 16% chromium steel. The amount of metal between the dies should be less than for mild steels; when the weld is complete the inside faces of the dies clear no more than $\frac{1}{16}$ in.

As the electrical resistance is approximately ten times greater, and the thermal conductivity 40% less than mild steels, it is evident that heat will be rapidly generated at the joint, yet carried back into the cold adjoining metal quite slowly. Furthermore, the operation is done quickly. The heat required will be about 15% less than for mild steel, and the speed of welding approximately 100% greater.

Since it is necessary to weld at high speed, no lag in electrical current can be tolerated. Hence the transformer bank must be of sufficient capacity. When welding mild steels a line drop at the welding machine of 10% is generally permissible, but 5% is the limit tolerated for stainless steel.



Finished Evaporator Unit for Monitor Top Refrigerator, Spot Welded From Two Stampings of 18-8 Stainless Sheet. Courtesy General Electric Co.

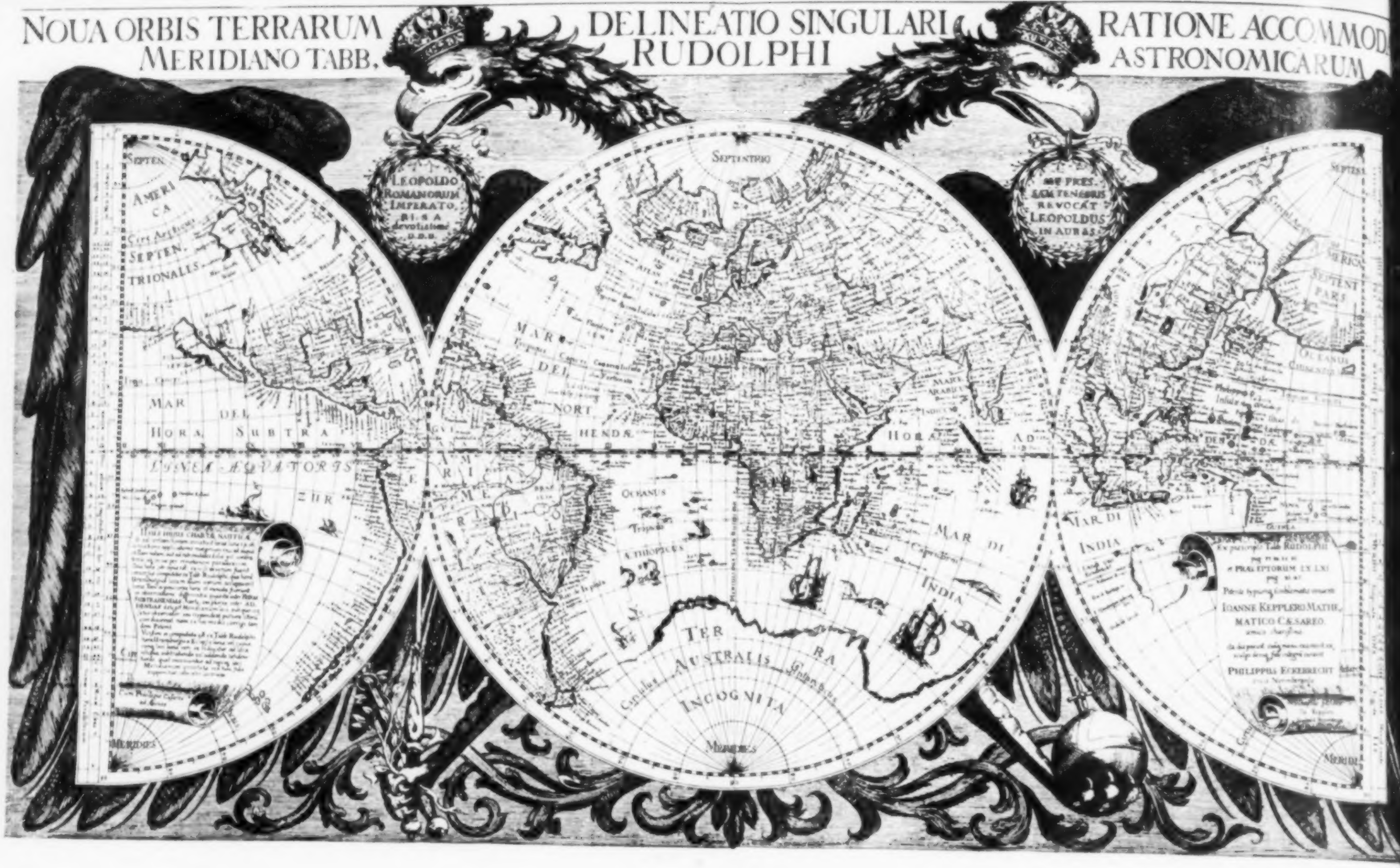
Rapid welding obviously necessitates rigid, well-balanced equipment which will not throw any shock or vibration into the hot work. Time must also be regulated accurately by positive, automatic mechanical and electrical control.

Control of time is doubly important when spot welding thin sheet of 18% chromium, 8% nickel steel, either in isolated spots or in overlapping spots making a seam, especially when the heat effect is to be so sharply minimized that the external surfaces do not reach the temperature at which carbides tend to precipitate. The process has been dubbed the "shotweld" process by the Edward G. Budd Mfg. Co., its leading proponent (see article by E. J. W. Ragsdale in METAL PROGRESS for July, 1933).

Time of current application may be controlled either by synchronous motor-driven cam-operated switches, or by thyratron vacuum tubes which can select even the correct time in the voltage wave. With the latter, seam welds are made automatically in 18-8 sheet by overlapping spot welds at the rate of 72 in. per min., record speeds of 600 spots per min. have been achieved.

A good example of the work done in this way is the evaporating unit for domestic refrigerators shown in the cut above. Two flat sheets are stamped so that, when laid face to face, the necessary chambers and passages are formed. They are spot welded on $\frac{3}{4}$-in. centers between corrugations, and seam welded completely around the edges. The unit is then bent into U form, and other attachments are made, usually by silver soldering.

Other interesting applications of spot welding 18-8 alloy are in the fabrication of light weight, high speed passenger trains, and deck structures for sea going vessels. For this work the stainless sheet and strip is cold rolled to an ultimate tensile strength of about 150,000 psi., and by design methods developed by aircraft engineers the metal is utilized so it has a strength-weight factor of 6 or 8 to 1 as compared with standard structural steel shapes.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The Bethlehem Exhibit *at the* National Metal Show

VISITORS to the National Metal Exposition will find working models depicting the operation of two Bethlehem departments which contribute importantly to Bethlehem's ability to serve present-day transportation and industry.

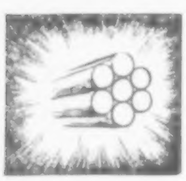
Heat-Treatment of Wrought Steel Wheels

*H*EAT-TREATMENT of the rims of wrought steel wheels, a development pioneered by Bethlehem engineers, gives Bethlehem Wheels great hardness and toughness, effectively armoring them against wear. These are the wheels that are in use on the Burlington's Zephyr and other fast trains of both the new light-weight and conventional types.

The working model at the National Metal Show portrays the entire heat-treatment process. You see the wheel enter and leave the furnace. You see it quenched, charged into the drawing furnace, taken by a crane to the cooling pit.

In addition to this working model, transparencies will depict the forging and rolling processes by which Bethlehem Wheels are made.

Electric Heat-Treatment of Bars



*B*ETHLEHEM'S electrically operated bar heat-treating plant is the largest in the world devoted to the hardening and annealing of mill-length bars. It embodies the most recent improvements in heat-treating practice, applying on a commercial scale the exact methods of the laboratory.

In the working model the automatic charging of the bars into the pre-heating furnace is shown, and their automatic transfer to the high-temperature furnace. The bars are then shown leaving the high-temperature furnace and being picked up by the crane, which carries them to the tank where they are quenched, after which they are deposited on the discharging rack.

Other noteworthy features of the Bethlehem exhibit will include the following products:

Bethlehem Alloy Studs and Bolts

THESE studs and bolts, made from specially developed alloy steels, are Bethlehem's answer to the need of industry, particularly the oil, power and chemical fields, for fastenings capable of long, trouble-free service in installations involving exposure to high pressures and high temperatures, and corrosive action.

The exhibit will also include Bethlehem Hot-Forged Nuts, Heat-Treated and Oil-Quenched.

Bethanized Wire

A BETHLEHEM development of far-reaching importance. Bethanized Wire is steel wire zinc-coated by a new process which results in lighter, purer, more ductile and heavier coatings than were ever before possible. Chain-link and farm fence and other products made from this new kind of zinc-coated wire will be exhibited.

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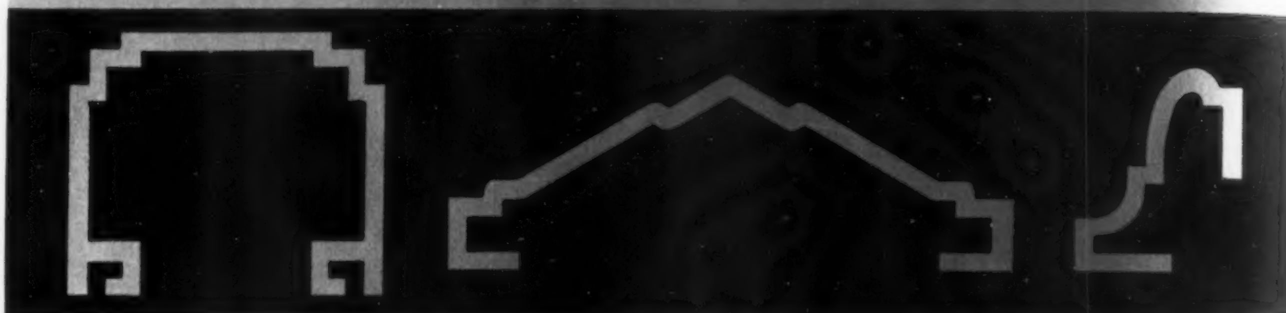

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NON-FERROUS METALS USED IN AIRCRAFT

By J. B. Johnson
Chief, Material Branch
War Department, Air Corps
Dayton, Ohio

AIR TRANSPORTATION TOOK THE role of a recognized competitor of other forms of transportation in the summer of 1929 when the United Air Lines initiated a 30-hr. service between New York and Los Angeles. It was not until about 4 years later, however, that the airplane designer and builder finally realized that the only excuse for air transportation is speed. That this idea flourished is demonstrated by the fact that whereas the cruising speed of the airplane selected in 1929 for the transcontinental air line was 100 miles per hr., the modern transport now cruises close to 200.

How is this performance attained? It is brought about by a cumulative improvement in *(a)* the aerodynamic properties, *(b)* power plant, and *(c)* materials. Before discussing the last in some detail, a few words about the first two are in order.

Improvement in aerodynamic properties by the reduction of parasitical resistance has nearly achieved its maximum. For instance, the 1929 all-metal biplane had an equivalent flat plate area of 25 sq.ft. This has been now reduced to 2 sq.ft. by elimination of wires and struts, by retractable landing gears, and by better streamlining, cowling and placement of all remaining elements.

The increase in speed obtained by greater horsepower is much more costly than that resulting from the reduction of resistance, but there is no apparent limit to it. Thus — the 1930 Mitchell Trophy races at Selfridge Field were won at 147 miles per hr. with Army pursuit planes; this had grown to 217 miles per hr. in 1934 with 700-hp. motors. The world's speed record is held by a Macchi airplane — 440 miles per hr. — but it has 3100 hp. Of course, metallurgy has played an important part in these powerful, efficient engines, but the present article has principally to do with the last item listed above — namely, materials for the structure.

The gross weight of the airplane may be conveniently divided into three parts; (1) structural weight, including wings, fuselage, chassis, controls, tanks, seats and furnishings actually essential for flight; (2) power plant, such as engines, propellers, accessories and starters; (3) the variable load, which includes pay load, fuel and oil, crew and instruments for navigation and communication. An analysis of several airplanes representative of different types in production in 1930 and again in 1935 indicates that the structural weight was 40% of the total in 1930 whereas it is now about 35% — a reduction of about 5% of the total for the most efficient design. (Commercial transports may be about the same as in 1930 due to the additional weight in furnishings for the comfort and convenience of passengers.) There has been no appreciable change in the percentage weight required by the power plant, both figuring about 20% of the total, although the available horsepower has increased. This means that the useful load in 1935 is about 45% of the total or gross weight, whereas it was only 40% in 1930. The 1930 estimates include not only transports with wooden wings and steel fuselage but also the aluminum alloy monoplanes with three engines then in use.

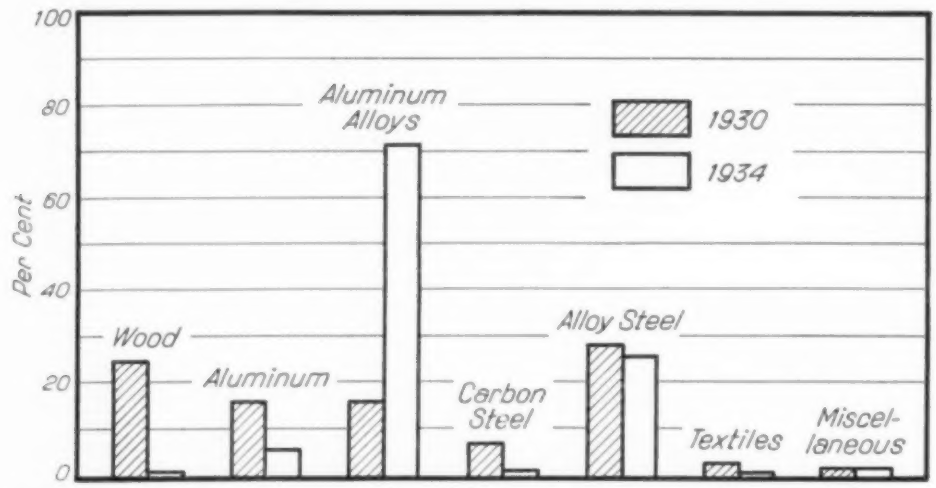
The diagram on the next page shows a comparison of materials used for large airplanes in 1930 and 1934. In both years a bomber and a transport were

analyzed. If we do not consider the small sport or private airplanes, all-metal construction might be called "aluminum alloy construction," as aluminum and aluminum alloys represent 75% of the structural weight. A reasonable estimate would be a total of 6,000,000 lb. of aluminum for airplane construction in 1935. The chart shows about 25% of the structure is steel (exclusive of engine, as above noted) and the small remainder is miscellaneous material including copper-base alloys, phenolic compounds and rubber.

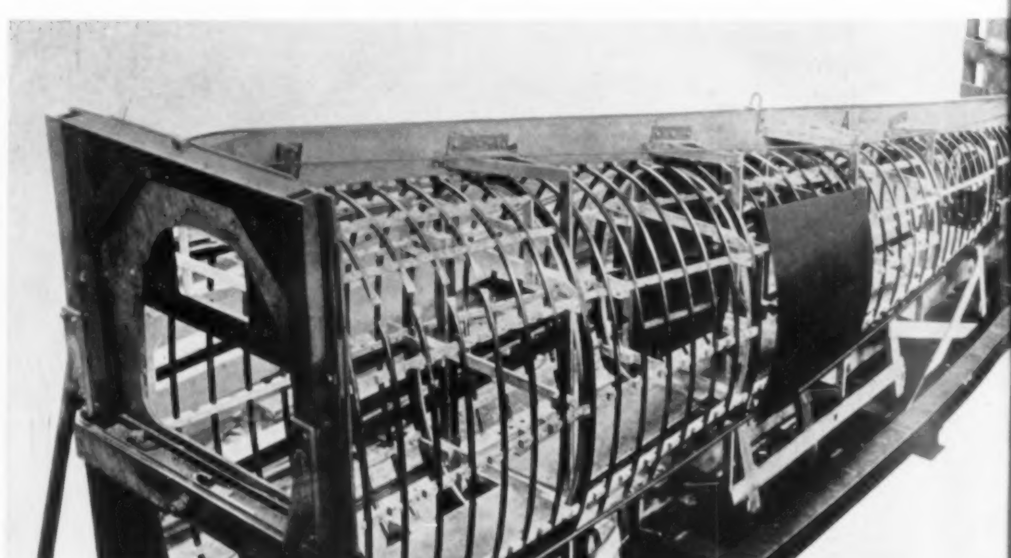
The selection of material for the airplane structure is influenced largely by basic design, which is often established by production costs and selling price rather than optimum efficiency. An excellent example of this is the development of the fuselage. The welded steel fuselage was at the peak of its popularity in 1931 and 1932, and is still the preferred type for small training and sport planes. But the trapezoidal shape is not good aerodynamically. It requires a false superstructure of stays and fabric — we might call it the hoop skirt age of airplane design.

The functions of a fuselage are to house properly the crew and load, to transmit the vertical, horizontal and torsional tail loads, and, in the single engined airplane, to carry the power plant — and to do all this with the least aerodynamic resistance and structural weight. When suitable materials were developed, it was only natural to build them into the structure so that they carried loads as well as gave the aerodynamic shape. Hence the industry has turned to the shell or monocoque, which we might similarly call the silhouette age of airplane design.

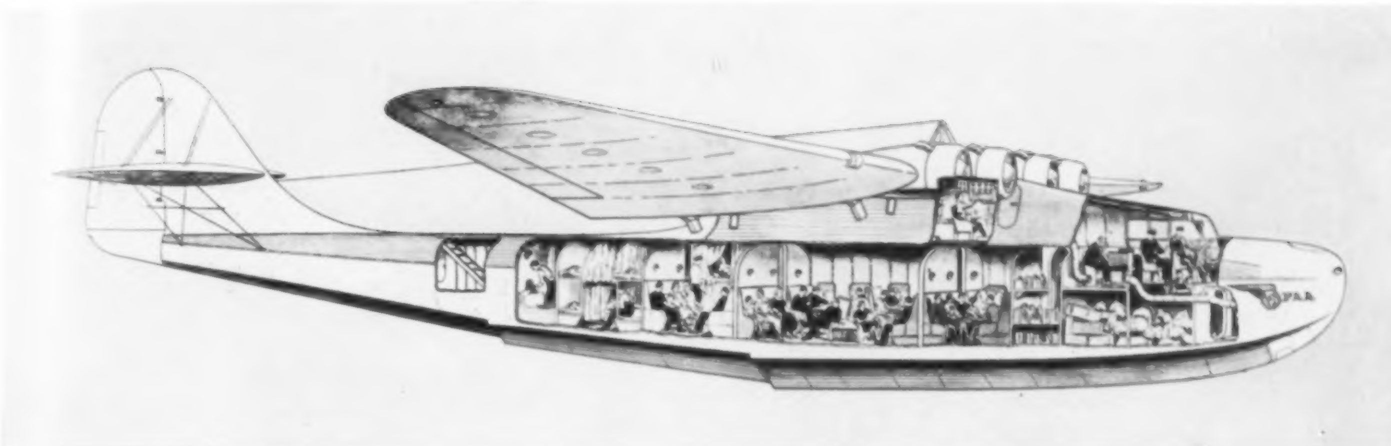
In its purest form it would be a shell without supports. If it could be built like an egg it would have great strength, but since there must be doors the semimonocoque has proved the most practical. As shown in the accompanying photograph of a fuselage section in an assembly jig, it uses a series of transverse bulkheads and rings to preserve the contour of the fuselage and a few longitudinals to stiffen the skin and assist it in carrying the vertical and horizontal loads from the tail. The skin must be of sufficient thickness so that when it wrinkles it will not take a permanent set. In the case of the more modern fuselages and hulls the aluminum alloy skin is laid flat on the inter-



Analysis of Materials of Construction of Structure of Large Bombers and Transports Shows That Aluminum Alloys Now Comprise About Three-Quarters of It



Semi-Monocoque Fuselage Section Being Assembled in a Jig. Note system of transverse bulkheads and rings to support skin, and a few longitudinals to assist skin in carrying loads from wings to tail. Courtesy Glenn L. Martin Co.



Phantom View of 25-Ton Flying Boat Constructed for Trans-Pacific Flights by Glenn L. Martin Co. for Pan-American Airways

nal framework. A corrugated reinforcement is sometimes used. The bulkheads are generally built-up frames with flanges for attaching the skin. Extruded sections in the form of bulb angles, tees and channels are popular.

This type of construction also makes available the maximum amount of space, as shown by the interior arrangement of the seaplane constructed for Pan-American Airways for the Trans-Pacific air line. This is the third largest seaplane ever built. It weighs 51,000 lb. and has a maximum speed of about 180 miles per hr. It will carry its full passenger load about 1200 miles.

There are two types of wing arrangement which have been used almost exclusively, the biplane and the monoplane. The biplane arrangement of two thin rectangular surfaces joined by a Warren truss is not particularly adaptable to all-metal construction; in it the conventional wing construction consists of two spars or beams to which the air load is transmitted through a system of ribs supporting a skin of doped fabric. Spruce and plywood are quite satisfactory and are used for most airplanes carrying up to three passengers.

The first shift to metal construction in wings of the larger planes was the substitution of metal ribs attached to wooden beams. This was followed by metal beams of many types, such as extruded aluminum alloy I-beams, welded and heat treated trusses of chrome-molybdenum steel tube, and built-up sections formed from thin sheet metal. No change was made in the arrangement of the beams and ribs, simply a replacement of wood with metal. These have been reasonably successful.

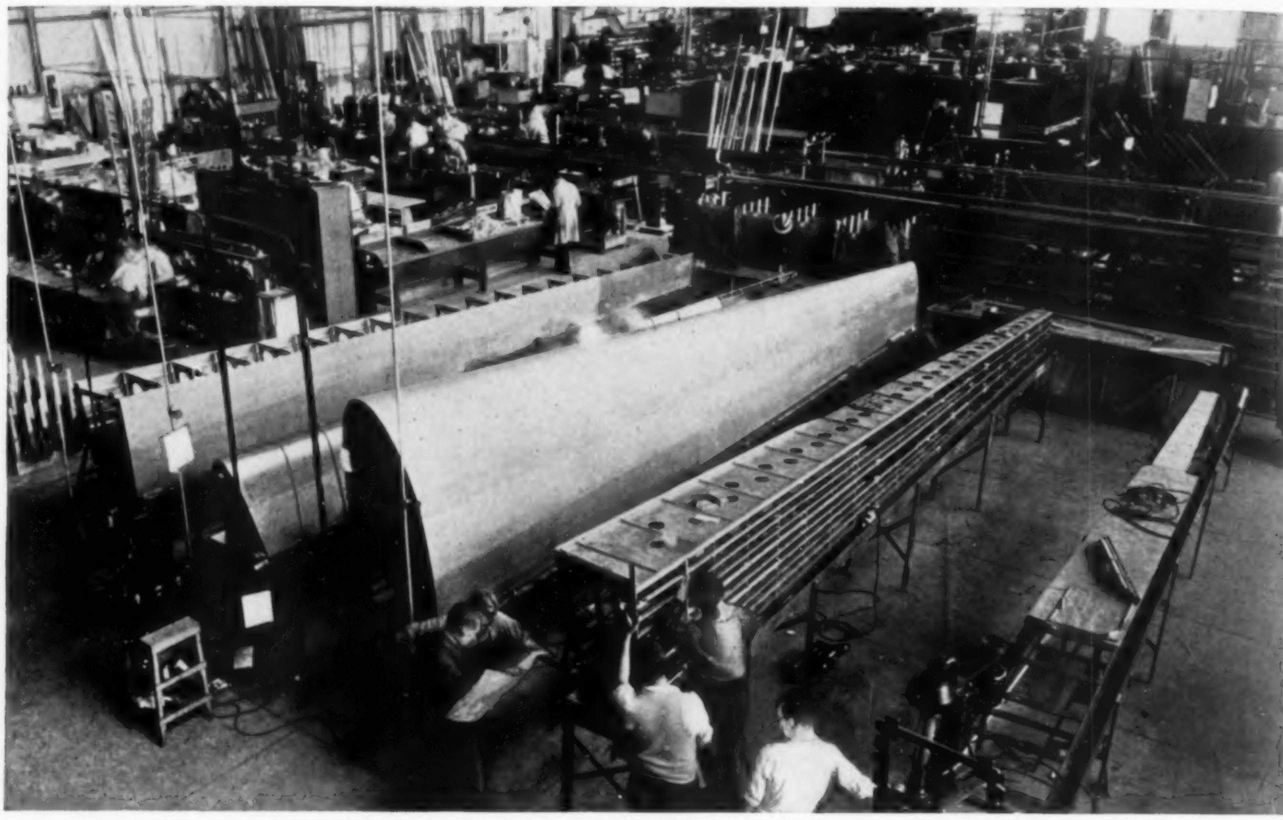
With the more general use of the monoplane with a thick cantilever wing which tapers both in the horizontal and vertical plane, new forms of construction have been evolved. The cantilever wing is heavily loaded at the root and if the wing can be made thick enough, there need be no external supports. The thickness at the root is seldom less than 10 in., and may be more than twice this. The conventional front and rear beams have therefore been discarded for a cellular structure fabricated from high tensile sheet.

As shown by the photograph on top the next page, this assembly is in effect a large box beam, which forms the middle section of the wing. It supports the principal flying loads and forms the attachment for the leading and trailing edges, which are often made detachable. The web members of the box are solid plates reinforced by vertical stiffeners but with practically no flange area. Top and bottom of the beam are made of a combination of corrugated and flat sheet, the latter on the outside to give a smooth skin and the corrugations to give longitudinal stiffness. Extruded shapes riveted to the smooth skin inside may be used instead of corrugated sheet.

Wrought Aluminum Alloys

Aluminum alloy construction is a symphony of rivet patterns. It requires more than 100,000 rivets to build a 14-passenger transport, and the present contracts for military airplanes will require more than 50 million rivets! There are two general types, one of which is driven within two hours after quenching (unless held at low temperatures to retard aging). The other type of rivet contains less alloying elements, and the alloy is such that it age hardens very little at normal temperatures and so may be driven any time after quenching. The allowable shearing strength of the former type is 30,000 psi., and the latter 25,000.

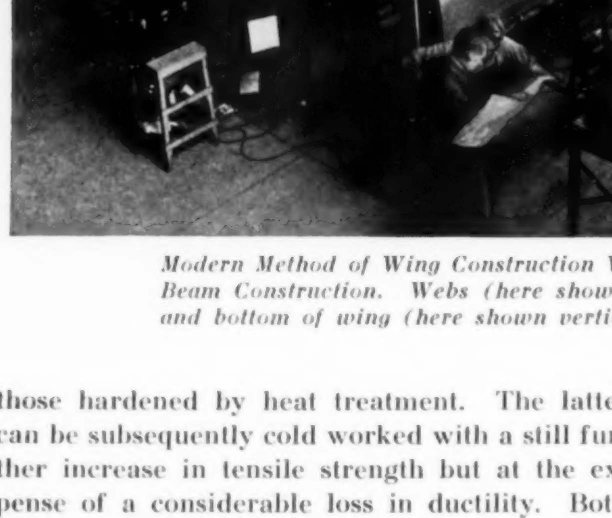
The wrought alloys may be classified as those which are hardened by cold work, and



Modern Method of Wing Construction Wherein Principal Loads Are Carried by Box Beam Construction. Webs (here shown horizontal) are of high tensile sheet, and top and bottom of wing (here shown vertical) complete the beam. (Douglas Aircraft Co.)

those hardened by heat treatment. The latter can be subsequently cold worked with a still further increase in tensile strength but at the expense of a considerable loss in ductility. Both types have been extensively employed in aircraft construction. Their chemical analyses, tensile properties and endurance are given in the large table on the opposite page.

The 99% aluminum alloy, often designated "pure aluminum," was at one time used universally for cowling, tanks, fairing and such parts. The desire for higher yield strengths has caused the adoption of a 1.5% manganese alloy for many welded tanks. The manganese-magnesium-aluminum alloy and the 2.5% magnesium alloy have also been used to a limited extent for ring cowls, fairing and in a few cases for control surfaces and structural parts to replace heat treated alloys.



Frequency Curves for Results of Tensile Tests on a Great Number of Aluminum Alloy Sheets, 0.015 to 0.168 In. Thick. Analysis: Copper 4.2%, magnesium 1.5%, manganese 0.6%, aluminum, remainder

The choice is often a compromise between strength and workability. In some designs the stresses are so distributed that the stiffness (as determined by the modulus of elasticity) is the controlling factor and since the modulus does not change with the alloy, the non-heat treated, lower cost alloy is used.

The alloy used almost exclusively for the structural members and highly stressed skin of the recent designs is a modified duralumin or super-duralumin designated 24-S by the Aluminum Co. of America. It has the same nominal composition as duralumin (4% copper and a small amount of manganese, silicon, and iron), but the magnesium content has been increased from 0.5% to 1.5%. The improvement in physical properties is worth while. The specification values for the new alloy are from 15 to 20% higher for the tensile strength and yield strength

with practically the same elongation. What this means to the airplane designer may be appraised by the statement that the saving in weight for one design in changing from duralumin (17ST) to super-duralumin (24ST) was 150 lb., or approximately 4% of the structural weight! It is remarkably uniform in properties; a frequency chart computed from tensile tests on specimens selected from every sheet used in a large production contract in the range of 0.015 in. to 0.168 in. indicates that the uniformity of this alloy is exceptional. The standard deviation is approximately 1600 psi. (See the chart opposite.)

This alloy can be aluminum coated in sheet form in a manner similar to "alclad," and in this form the material, now standard for seaplanes and amphibians, will come into more general use as an unpainted covering for airplanes. A recent example of the efficacy of alclad is the history of two Ford airplanes which were flown in the Middle West approximately 1200 hr. over a period of 4 years. One was finished with unpainted duralumin and the other with unpainted alclad duralumin. An examination indicated no visible deterioration but the tensile properties of the alclad material equaled those of the original, whereas the uncoated sheet had lost 20% of its tensile strength and 80% of its ductility.

Aluminum alloy castings fully heat treated by a solution treatment, followed by the aging treatment, have been used extensively in aircraft construction for brackets, rudder pedals, hinges, control arms, bearings and other parts.

The accompanying table gives the typical analysis and principal mechanical properties of the light alloys used for the structure and engine parts, together with a brief list of common uses. One or two footnotes are necessary. The fatigue limits were determined on R. R. Moore rotating beam machines, the specimen being machined from bars and forgings less than 1 in. diameter, and the cast specimens tested full size without machining. Tests were carried out to 500,000,000 cycles except those marked (a) which have been carried out to only 100,000,000.

Magnesium Alloys, Cast and Wrought

Magnesium alloy sand castings have been used continuously for aircraft engine starter housings since 1924. They are now used quite extensively for engine parts such as rear accessory cases and blower sections, oil pans, oil pumps, camshaft bearings and rocker box covers. The change to a magnesium casting for a rear section of an engine casing was responsible for a saving of 30 lb. in one noteworthy case. Some such castings have also been used for foot

Light Alloys Used in Aircraft Construction

Nominal Composition; Per Cent						Tensile Strength	Yield Strength	Elongation in 2In.	Brinell Hardness	Fatigue Limit	Uses
Al	Mg	Cu	Si	Mn	Others						
						Sheet, Tubes, Bars					
99						16,000 (c)	14,000	3 to 7 (e)		7,000	Cowling, tanks
Rem.				1.3		19,500 (c)	17,000	3 to 8		9,500	Do.
Rem.	1.2			1.2		35,000 (c)	31,000	3 to 8		9,000	Fuel and oil line, fairing
Rem.	2.5				Cr 0.25	34,000 (c)	24,000	5 to 10			Fuel and oil line, fairing, airfoil covering
Rem.	0.5	4		0.5		55,000 (d)	30,000	16%	100	13,000	Fittings, airfoil covering, structure
Rem.	1.5	4.2		0.6		62,000 (d)	40,000	15	105	14,000	Do.
Rem. (b)	0.5	4		0.5		50,000 (d)	27,000	16			Do.
Rem. (b)	1.5	4.2		0.6		56,000 (d)	37,000	15			Do.
						Forgings					
Rem.	0.4	4.4	0.8	0.8		65,000	50,000	10%	130	14,000	Airplane fittings
Rem.		4.5	0.8	0.8		55,000	30,000	16	100	14,000	Propellers, airplane fittings
Rem.	0.6		1		Cr 0.25	43,000	34,000	12	90	10,500	Crankcases, engine housings
Rem.		4.5	0.8	0.8	Sn 0.05	60,000	40,000	12	120	14,000	Propellers, fittings
Rem.	1	1	12		Ni 1	52,000	40,000	5	110	14,000	Pistons
Rem.	0.5	4			Ni 2	55,000	35,000	10	90		Pistons
6.5	Rem.			0.3	Zn 0.8	40,000	23,000	6	60	14,000	Propellers, engine housings
						Castings					
Rem.		4				32,000	18,000	3%	80	9,000	Airplane fittings, wheels
Rem.	0.3		7			30,000	20,000	3	90	8,000	Airplane fittings, wheels, crankcases
Rem.			5			18,000	7,000	6.5	40	5,000 (a)	Fuel line fittings, carburetors
Rem.	4					21,000	10,000	5	50	5,000 (a)	Carburetors, fittings, fuel injector bodies
Rem.	0.5	1.2	5			32,000	20,000	1	92	7,500	Liquid-cooled cyl. heads and jackets, crankcases
Rem.	1.5	4			Ni 2.0	32,000	20,000		100	8,000 (a)	Air-cooled cyl. heads, pistons, bearings
Rem.	0.2	10				35,000	29,000		100		Do.
Rem.	10					40,000	22,000	11	85	7,500	Airplane fittings
Rem.		4	5			32,000	18,000	2	60		Die castings
Rem.			12			33,000	16,000	1.5	80		Do.
10	Rem.			0.1		30,000	18,000	1	65	9,000 (a)	Engine castings, wheels

(a) See text (b) Aluminum coated material (Alclad) (c) Cold rolled sheet, ½ hard (d) Quenched and aged (e) Varies with thickness

control pedals and for accessories on seats and floor, and for landing gear wheels. Magnesium alloys are not recommended for water-cooled cylinder blocks or air-cooled cylinder heads or pistons — that is, for parts requiring high strength at elevated temperatures.

An aluminum-manganese-magnesium alloy with a tensile strength of 40,000 psi. in sheet and extruded shapes has been used in connection with fuselage cowling, seats and fairing. Such uses are more extensive abroad than here. In Europe magnesium alloys are frequently used for propellers, cowling, fuel tanks, and some structural members.

The greatest drawback to the more extensive use of magnesium is its lack of resistance to corrosion in salt air or salt water. A treatment consisting of a dip in a solution of nitric acid and potassium dichromate produces a surface film which forms some protection against corrosion, but its principal value lies in the improvement of the surface as a base for paint coatings. A good solution for this purpose is made in the following proportions: HNO_3 20 c.c., $Na(CrO_3)$ 15 grams, water 80 c.c.

Copper-Base Alloys

Copper and copper-base alloys have a very limited application to the airplane structure on account of their high specific gravity. Copper is used for radiators and fuel lines. The latter are now soldered with a lead-silver solder containing 5% silver which has a strength at operating temperatures more than three times that of the common lead-tin solder. Some other properties (as well as of cadmium-silver solder) are given in the table below.

Tests on Light Alloys at -40°F.

		Duralumin (25-S)	Aluminum Alloy Casting	Magnesium (9% Al, 0.5% Zn)
Tensile strength	+70°F.	55,000 psi.	39,000 psi.	48,000 psi.
	-40°F.	58,000 psi.	39,000 psi.	58,000 psi.
	Change	+5%	0%	+20%
Yield strength	+70°F.	30,000 psi.		38,000 psi.
	-40°F.	31,500 psi.		40,000 psi.
	Change	+5%		+5%
Elongation in 4 dia.	+70°F.	16%	1%	8.5%
	-40°F.	13%	1%	7%
	Change	-18%	0%	-18%
Reduction of area	+70°F.	22%		12%
	-40°F.	20%		7%
	Change	-9%		-42%
Izod impact	+70°F.	13 ft-lb.		3 ft-lb.
	-40°F.	13 ft-lb.		2 ft-lb.
	Change	0%		-33%
Brinell hardness	+70°F.	102	121	74
	-40°F.	105	115	78
	Change	+3%	-5%	+5%
Fatigue limit	+70°F.	13,000 psi.	7,000 psi.	15,000 psi.
	-40°F.	16,000 psi.	8,000 psi.	18,000 psi.
	N=	500 x 10⁶	300 x 10⁶	300 x 10⁶
	Change	+23%	+14%	+20%

Properties of Solders

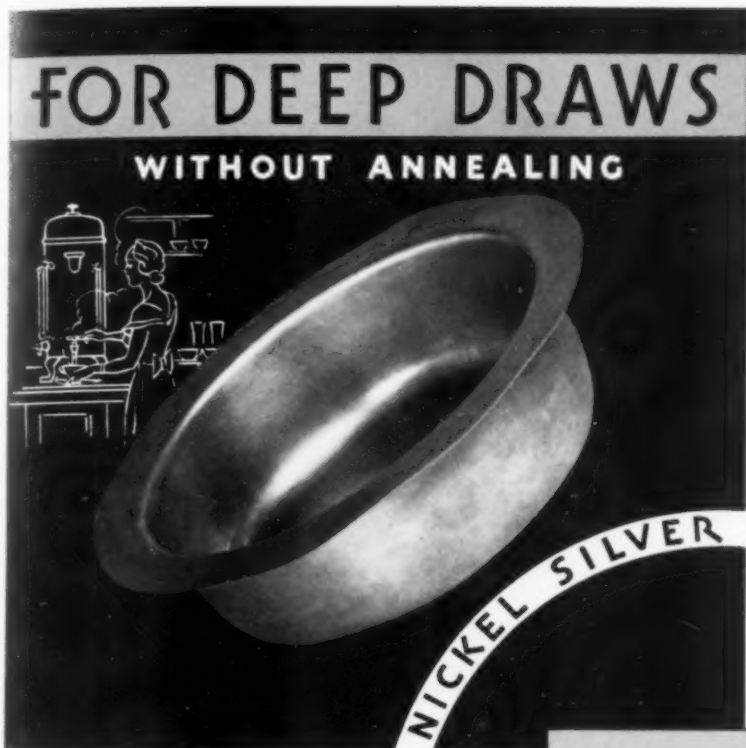
	Lead-Tin (50% Pb, 50% Sn)	Lead-Silver (94% Pb, 6% Ag)	Cadmium-Silver (99% Cd, 1% Ag)
Melting range	370 to 450°F.	580 to 700°F.	610°F.
Shear at 70°F.	2580 psi.	2470 psi.	2180 psi.
Shear at 350°F.	441 psi.	1556 psi.	2205 psi.

High tensile bronze is used to some extent for landing gear and tail wheel fittings. The lack of uniformity in the properties of the casting has been a drawback. The specification requirements of 100,000 psi. tensile strength, 60,000 psi. yield strength, 20% elongation, and Brinell 205 can be maintained on test bars, but sections cut from castings are generally 25% lower in strength, and the elongation may be very low (3.5%). Analysis of one such bronze is 58% Cu, 1.7% Fe, 3.0% Mn, 3.8% Al, remainder zinc. The silicon-copper bronzes, containing 3% silicon and about 1% manganese or zinc have been used for fuel line tubing and for castings in fuel and oil lines as a substitute for red brass (85 Cu, 5 Sn, 5 Pb, 5 Zn).

Beryllium-copper alloys have found use in small flat and helical springs to replace phosphor bronze, since the proportional limit is consistently higher than for phosphor bronze after the fabricated spring has been given an aging treatment by heating for 6 hr. at 525° F.

Nickel Alloys

Stainless steels of the 18% chromium, 8% nickel type, low in carbon and "stabilized" with titanium have given very satisfactory service for exhaust manifolds and stacks. "Inconel," a high nickel-chromium alloy with little iron, also resists corrosion by exhaust gases containing lead bromide from the burning of doped gasoline. It has the advantage of being free from carbide precipitation at red heats. It does not cold work as rapidly as the austenitic corrosion resistant steel and welds readily to form a ductile seam. Service tests indicate *(Continued on page 130)*



The shell at the left, a coffee urn lid in the making, was drawn to a depth of 5¼″ in a single draw, from a 20-gauge Seymour 18% soft Nickel Silver circle 21″ in diameter. No giant press was used; the work was done on a No. 2½ Bliss Draw Press.

Absence of annealing, a process which softens a shell all over, is an advantage, as it preserves strength where strength is needed—at the top in this case.

Seymour Nickel Silver is a highly ductile alloy. In drawing or spinning, it flows smoothly without strain. Coming out free from splits and open pores, it usually avoids the grinding operation. Also an advantage, where the article is to be silver plated, is the silvery white color of Seymour Nickel Silver, which, when exposed by wear, matches the surrounding plate.

The rotating assemblies in the 250-volt, 60-ampere heavy duty switch at the right are made of Seymour Phosphor Bronze because of its strong spring tension and good conductivity.

At each "ON" throw of the switch, these assemblies, composed of two plates, are driven into contact with terrific force by heavy coiled springs, the impact separating the plates to effect the grip on the contact plate. This grip must be sustained for many years; and, to make sure of it, the assemblies are put through a "fatigue" of 50,000 impacts! Evidence of the ability of Seymour Phosphor Bronze to stand such rigorous service is the fact that it is used for just such purposes by a very important part of the electrical industry.

If you wish samples of Seymour Nickel Silver or Phosphor Bronze for test purposes, please call on us at any time.

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Specialists in

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AIRCRAFT ALLOYS

(Continued from page 128) that the annealed and sand blasted Inconel resists atmospheric corrosion better than 18-8 in the same condition.

Use of corrosion resistant steel for the main structural members of aircraft is still in the experimental stage. Progress has been retarded due to the lack of design data which must be accumulated before the strength-weight ratio of the structures will compete favorably with aluminum alloys.

Properties at Low Temperatures

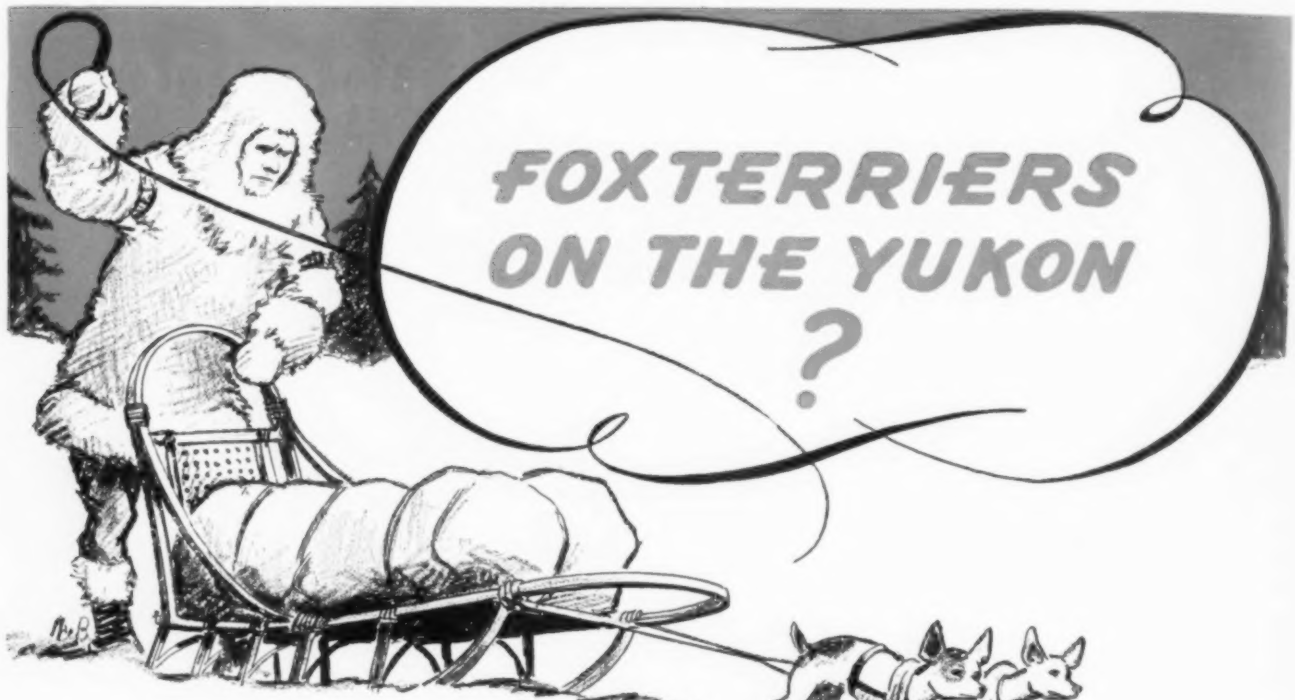
The certainty that aircraft will operate at low temperatures in the range of —50° (corresponding to approximately 30,000 ft. altitude) has led to rather complete tests to determine the effect of such temperatures on the materials of construction. The cold room at Wright Field is equipped with rotating beam fatigue testing machines, an Izod impact machine, Brinell hardness tester, and tension testing machines. Most of the fatigue and tensile results have been obtained at —40° F. Notched bar impact tests have been made at several temperatures down to —55° F.

All the metals used in the structure of the airplane have a greater tensile strength and higher fatigue limit at —40° F. than at 70° F. The effect on ductility as indicated by elongation and reduction in area is erratic, but not particularly significant. (An exception is 18-8; annealed samples have these values lowered, but in cold drawn and cold rolled samples they are markedly increased.) Figures are given in the table on page 128.

Stratosphere flying opens up fascinating problems. The lower density of the air, which at 30,000 ft. is only 37% of that at the earth's surface, must be counteracted by supercharging so that the normal 16 to 1 ratio of air to fuel on the ground will be maintained. Controllable pitch propellers, which will permit resetting to obtain greater angles in the less dense atmosphere, are essential. Low density air has less resistance and meteorological observations indicate that prevailing winds are steadier and have a high velocity. For high altitude flights, passenger and pilot compartments must be sealed so that the pressure and the oxygen content will be equivalent to the conditions existing at about 10,000 ft. These conditions bring up new metallurgical problems.

This paper has covered briefly the present status of metallurgical development and its effect on basic design. Not only has performance been improved but safety, a primary requisite for all forms of transportation, has been enhanced. There were no airplane accidents on regular transport air lines in 1934 which the Bureau of Air Commerce analyzed as structural failures during flight. Progress in aviation has been steady throughout the depression. The passenger miles flown in 1934 show a gain over 1933. *Aviation Magazine* estimates a dollar business this year that will be 50% greater than 1933. Engineering developments are still toward increased speed; in fact, the 300 miles per hr. transport is a distinct possibility in the near future. Engine power is being increased through refinement of design, such as vibration dampeners and fuel injection systems. Fuels with a 100% octane rating are procurable, which have improved the horsepower outputs from 15 to 30%.

We are on the threshold of extensive experimental flying at higher altitudes to determine the practicability of transporting passengers under these conditions. It is achievements of this type in all fields that will give the impetus to another era of expansion.



Foxterriers on the Yukon would prove equally hazardous as an attempt to use an untried electrode on a corrosion or heat resisting alloy . . . Equivalent dependence must be placed on these alloys as directly compared to the life, property and reputation glorified by the huskies on the long pull in the north.

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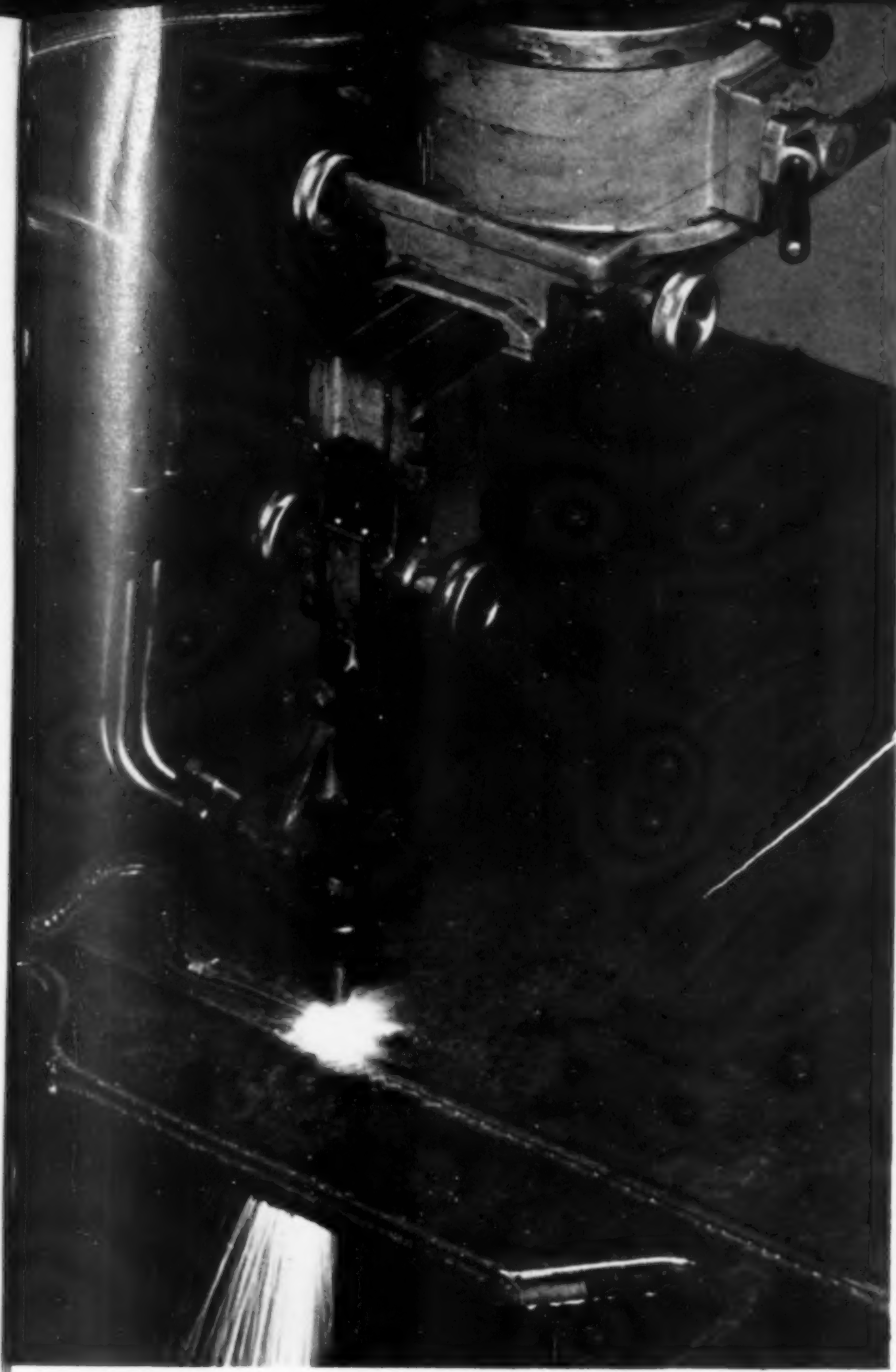
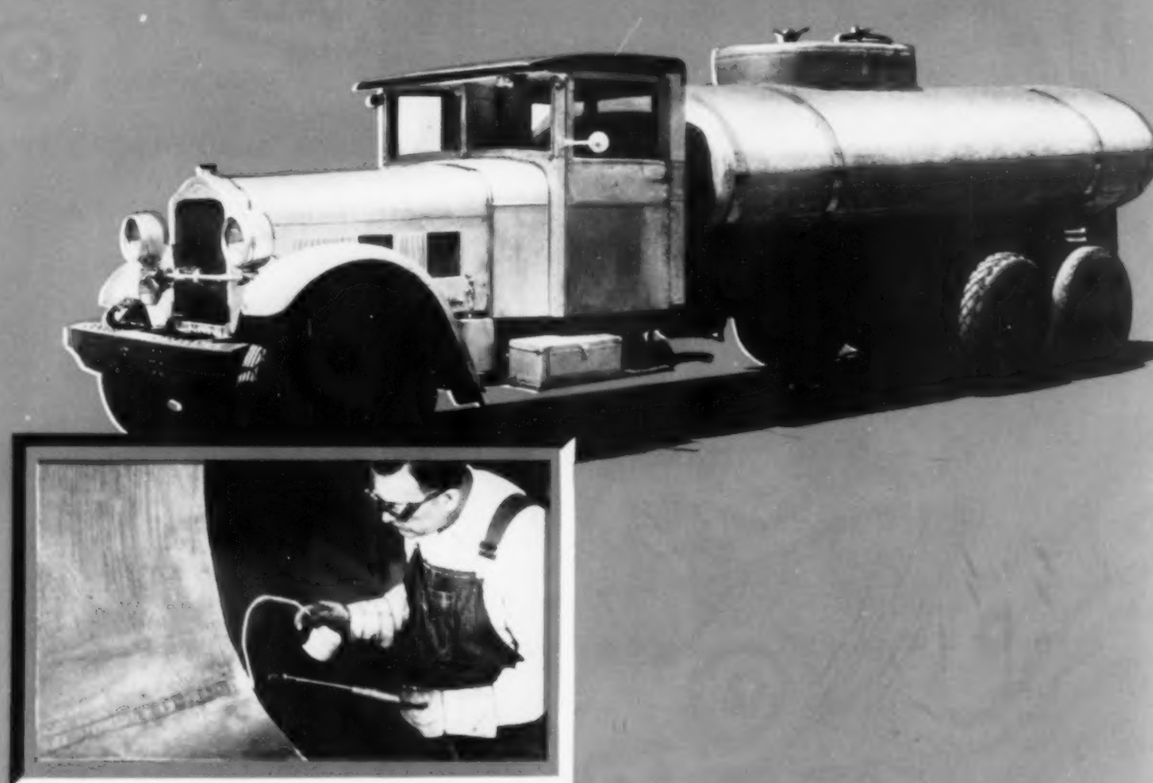


WELDING AND CUTTING

Welding—Obviously Excellent for Joining Two Pieces of Similar Metal—Is Also Capable of Making Composites Whose Parts Are Chosen for Special Purposes . . . Hard-Facing, Either With Oxy-Acetylene or Electric Arc, Is Such a Process, Now Widely Used in Many Industries



EDITORIAL NOTE

The advantages of hard metal facings need not be expounded at length to a group of men who are familiar with carburized and case hardened parts. Modern welding methods and exceedingly hard alloys enable the engineer to surmount the limitations of such high carbon steel surfaces (although it is obviously possible to use a high carbon steel welding rod for making a hard surface on a soft backing much thicker than could readily be done by carburizing).

These special hard-facing materials are now marketed with a wide range in hardness, abrasion resistance and toughness. All of them have a considerable degree of hardness as welded, ranging from Rockwell C-40 upward, and these figures generally are largely increased by cold work (either peening in the shop or battering in service). As indicated by Mr. Brown in his article which follows, these may be classed in several groups — medium alloy steels, high alloy austenitic steels, high alloys with iron as a minor element, non-ferrous alloys, and carbides or diamond substitutes. Each of these may be illustrated by an important example.

In the medium alloy steels may be classed the tungsten-molybdenum high speed steel described by Frank Garratt in the June issue. He wrote only of its use in forged and heat treated tools for machine shop use, but it has been discovered that it welds excellently (despite the inability to do much in this line with the standard high speed — 18% tungsten, 4% chromium, 1% vanadium) and in multiple layers has a hardness of C-62 as welded and very good abrasive resistance and cutting ability.

The best-known representative of the austenitic steels for resisting heavy impact abrasions is, of course, the cast Hadfield's manganese steel (10 to 14% manganese and 1.10 to 1.40% carbon). This alloy must be drastically quenched after casting and hardens only on subsequent cold work. Obviously its use as a welding rod presents great difficulties, and these have been largely avoided by lowering the carbon content and adding 3 to 5% nickel. As indicated by Hall in Metal Progress for November, 1931, this modified alloy is austenitic after air cooling; it also has the desirable work hardening qualities of the original variety. Another modified welding rod of this family has a considerable addition of tungsten.

Next come alloys known by various proprietary names having up to 50% of alloying elements with iron. Chromium and manganese, with or without tungsten and molybdenum, are favorite ingredients. These, to be valuable, are alloys which are hard in the as-cast condition and generally are useful where conditions are not too severe. They were primarily developed for customers who were unwilling to pay the high price for the intrinsically hard, iron-free alloys, well known as stellite, and it is probable that their popularity is

(Continued on page 145)

HARD-FACING MATERIALS & METHODS

By R. E. Brown
Sales Engineer
Electro Metallurgical Sales Co.
San Francisco, Cal.

THE PROCESS OF HARD-FACING CONSISTS in welding a coating of a wear resisting alloy $\frac{1}{16}$ to $\frac{1}{4}$ in. thick to the wearing surfaces of a metal part. High quality materials for this purpose should possess the following properties:

A. Inherent hardness.

B. "Red-Hardness," or ability to retain initial hardness up to red heat and to be unaffected after cooling slowly from red heat.

C. Resistance to abrasion during use.

D. Resistance to high temperature oxidation during its application.

E. Melting point slightly lower than steel, the usual base metal.

F. Coefficient of expansion close to that of the base metal.

G. Easy application by ordinary technique.

H. Ability of being applied with minimum effect on the structure of the base metal.

This is a rather formidable combination, and approached by but few materials. Nevertheless, in the 12 or 15 years in which this matter has been vigorously pressed by various branches of the welding industry, a great number of welding rods, hard inset particles, and special welding techniques have been exploited. They may be roughly classified as follows:

Group 1. Alloys of low cost per pound, practically all of which are merely high carbon steel or hard cast irons with or without a little alloy. They are generally rather brittle and adhere rather poorly. They have had very little success in severe duty and are limited to applications where a hard steel or iron part would be satisfactory.

Group 2. Metals that are essentially austenitic alloy steels containing varying amounts of chromium, tungsten, manganese, or silicon, the total of all usually below 20%. Such alloys have considerably greater wear resistance than any ordinary car-

ron steel, especially if they possess properties somewhat similar to 13% cast manganese steel. They are intermediate in unit cost. They make an excellent filler rod for rebuilding badly worn parts where service involves considerable heavy impact rather than scour. As they are usually quite tough and ductile, they serve well as a building-up material over which is to be placed a final harder surface.

Group 3. Metals that contain more than 20% and as much as 50% of one or more of the elements chromium, tungsten, manganese, silicon, cobalt, nickel, and carbon. With this group we encounter the first true hard-facing metals, in the sense of materials which do not need to be cold worked to induce hardness (like most of those of Group 2) but whose hardness is intrinsic.

Group 4. This class consists of a group of non-ferrous cobalt-chromium-tungsten alloys of which Haynes' stellite is the exclusive representative. The iron content is negligible. Several different grades of the alloys are all highly resistant to abrasive wear but vary in strength and toughness. In this material cobalt is the base of the alloy, whereas iron is the base of all alloys in preceding groups. Its hardness is inherent and permanent in that it may not be altered by heat treatments up to 1650° F.

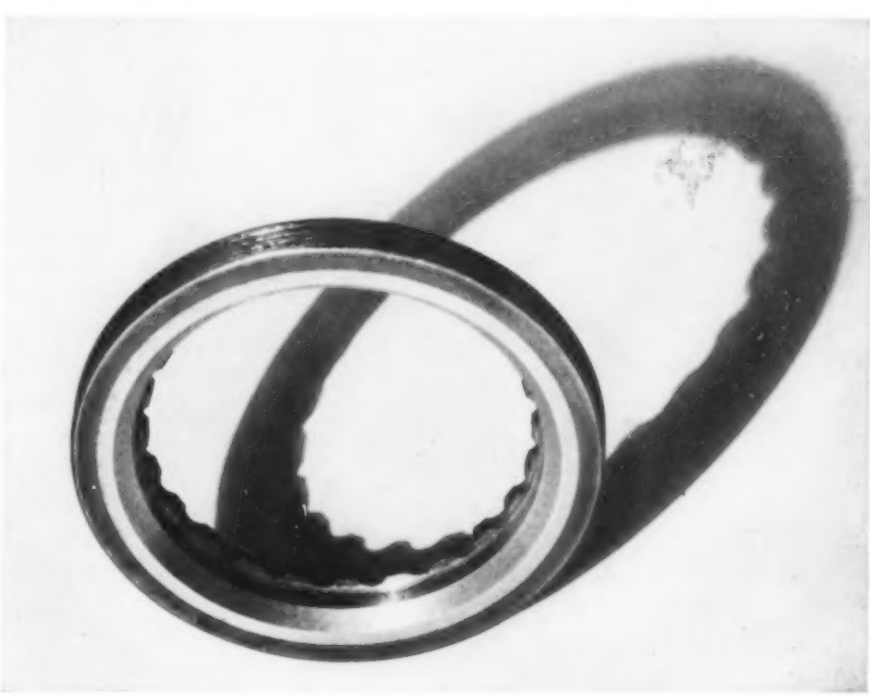
Group 5. Tungsten carbide and other diamond substitutes. These usually consist of 90 to 95% tungsten carbide with a ductile metallic binder. Tungsten carbides cannot be melted with the oxy-acetylene flame, so they are furnished in the form of small castings of various shapes, which are "wetted" and anchored in place on the surface of the part being hard-faced by means of another hard-facing metal frequently referred to as the tie-in rod. A tough, hard, tie-in metal is desirable so as to support the pieces firmly and prevent undermining the hard particle. Their largest use is on oil well drilling tools, for boring through solid rock.

Group 6. This subdivision comprises combinations of hard-facing alloy and crushed tungsten carbide, made in various forms.

Selection of the most suitable hard-facing metal for each particular job must take into consideration finished cost, maintenance, cost of shut-down for repair or replacement, and projected service life. As a rule, the higher quality will prove the more economical in the long run, despite its comparatively high first cost. From tests of alloys from each of the foregoing groups in strictly comparative service, a prediction of the relative service life can be made. Using the life of carbon steel as unity, these will be about as follows:

Hard steel	1
Group 2	1.5 to 2
Group 3	2 to 4
Group 4	3 to 10
Groups 5 and 6	10 to 20

Before passing on to some data on the proper methods of welding, a few remarks on the nature of abrasion resistance are in order. Testing for wear resistance is an art not yet properly developed; figures cannot be established representing the wear index of a specific metal, such as can be found, for instance, for its tensile strength. It is belived that wear involves close rubbing contact, without lubrication, of tiny areas on two surfaces, and the molecules or particles at these contacting points become softened by the frictional heat and are torn away while in a relatively soft condition. Hence the paramount importance of what may be known as "red hardness" in materials that are to resist wear, that is, the ability to retain their initial hardness up to red heat and to be unaffected after cooling slowly from red heat. One alloy may possess a higher hardness than another at room temperature, yet the latter, if it retains its initial hardness at elevated surface temperature while the first



Exhaust Valves on Heavy Duty Gas Engines (As for Trucks and Busses) Are Much More Durable Than the Seats in the Cast Iron Cylinder Block, so Many Valve Seat Inserts, Faced With Heat Resisting Materials, Are Used to Lengthen Mileage Between Grinds

does not, will prove to be the superior wear resisting alloy. Hence the well known fact that the Brinell hardness impression is not nearly as indicative of wear resistance as is the scratch or file hardness — a test which imitates actual abrasion.

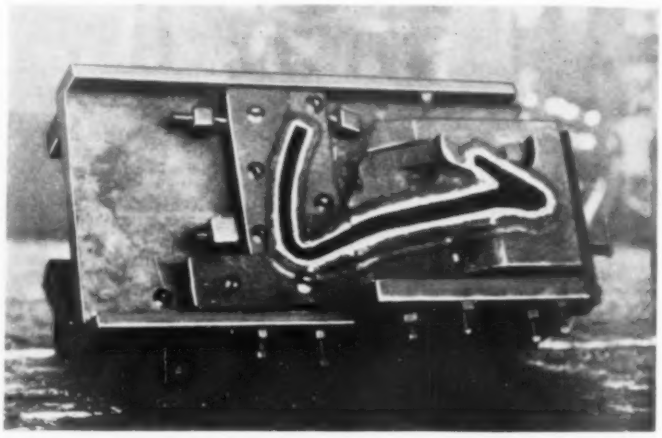
Instantaneous temperatures generated by friction are far higher than would be surmised. Surface temperatures of bodies sliding over one another under pressure often approach red heat, although there may be no visual evidence because the heat is rapidly dissipated into the body of the metals and the air. Thus, if the ends of two thermocouple wires be merely held against a rotating steel disk, a temperature of 1500° F. will be indicated, but to the eye there is no evidence of heat. Hence the ability of a hard-facing metal to resist wear must be determined under actual working conditions.

All alloys will soften as temperature is increased but the rate of softening varies. High speed steel softens less rapidly than carbon steel, and the cobalt-chromium-tungsten alloys of Group 4 soften least of all. In fact, the iron content of a hard-facing alloy is inversely proportional to its comparative red hardness; with even a little the rate of softening increases and continues to do so in alloys successively higher and higher in iron. At temperatures above 1100° F. the cobalt-chromium-tungsten alloy Haynes' stellite has a higher hardness than any other known metallic alloy; in fact, it retains almost its original hardness up to temperatures of approximately 1800° F.

High Pressure Steam Also Ruins Valve Gates and Valve Seats by the So-Called Wire Drawing Effect, But This Is Effectually Prevented by Welding a Ring of Stellite at the Closure and Grinding to a Perfect Seat

Welding Methods That Are Suitable

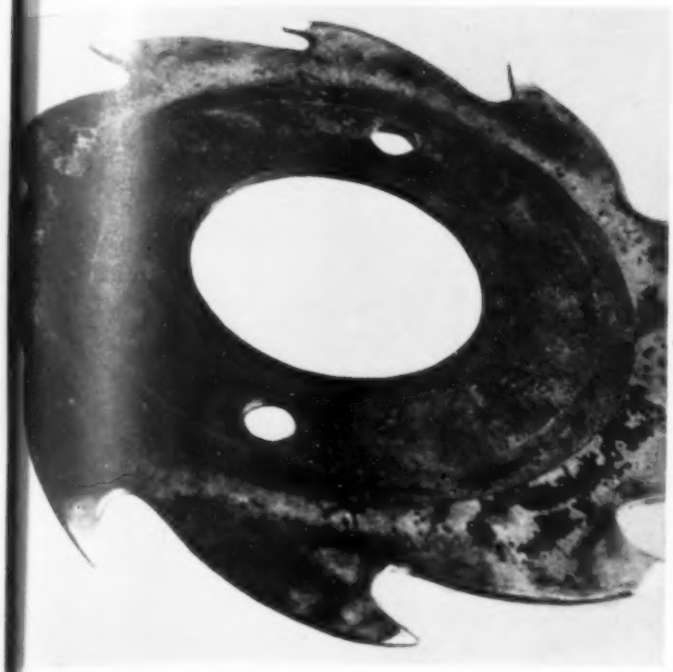
Both the oxy-acetylene and electric arc welding processes are used for hard-facing. It is impossible to divide the field sharply, as both processes have certain advantages depending on the nature of the hard-facing metal, the size and shape of the part, and general conditions pertaining to each job. The use of the oxy-acetylene process is distinctly preferable in the application of the non-ferrous cobalt-chromium-tungsten alloys (stellite) comprising Group 4, due to one important factor which applies to a marked extent in the use of any rod for hard-facing. This is the matter of adherence, or bonding without extensive alloying into the base metal.



Forging and Trimming Dies and Shear Blades for Hot Metal Give Much Trouble When Worked So Rapidly That They Cannot Be Effectually Cooled; Only High Alloys on Surface (or Solid) Will Then Stand Up

This process of welding on without much melting of base metal is a distinct, though very simple, form of the welding art, having far wider application than mere hard-facing. In joining two adjoining metals by ordinary welding it is advisable to secure a certain amount of interalloying between body metal and weld metal; this action is commonly known as "penetration." This is quite all right when base metal and weld are of equivalent nature and composition, but it is objectionable in hard-facing as it results in dilution of the expensive surfacing material.

If the hard-facing metal can be applied without puddling the base metal and yet maintain a close bond or adherence with that body, it then possesses some of the eight properties



Knives for Shredding Paper Pulp Cost $200 per Set When Made of High Carbon Steel and Last One Month; the Same Knives, Tipped With Hard Facing Alloy at a Cost of $90 Last Six Months

described at the outset as paramount in a high quality hard-facing alloy — its melting point is a little below that of ordinary carbon or low alloy steel, its coefficient of expansion is closely similar to steel, its application does not appreciably affect the base structure, and it welds easily.

A certain amount of inter-alloying is unavoidable, although it can be kept at a minimum through careful control. For coverage of large area the electric arc process is economical and is frequently employed if rough surfaces and some cracking or checking of the hard-facing metal are not objectionable. Reversed polarity should be the rule in depositing all high chromium alloys with the arc. Power consumption is fairly heavy.

Oxy-Acetylene Technique

The practice to be pursued with the oxy-acetylene flame may vary slightly depending upon the nature of the metal being deposited. Having had the most of my experience with Group 4 alloys, I will describe the process as practiced in the use of Haynes' stellite, but fundamentally a similar method should be pursued for applying any hard-facing alloy by the oxy-acetylene method. The recommended practice is somewhat similar to brazing, but it is actual welding without appreciable penetration.

Surfaces to be hard-faced should be cleaned of scale or other adhering foreign matter. The blowpipe should be adjusted to a carburizing flame with the tip of the outer cone extending almost three times the length of the inner cone. A tip sufficiently large to hold the heat in the body metal should be used so that this surface will "sweat." As in the method of rapid welding described in Metal Progress just a year ago, the flame lends a little carbon to the hot (unmelted) steel, converting a very thin surface film to a high carbon steel with a much lower melting point. Hence this film will glaze over, and the surface appear to "sweat" before any measurable part of the base metal steel is heated to its real melting range. When this occurs the rod of stellite should be held directly beneath or beside the flame (never ahead of it), and as the alloy melts from the rod it will spread freely over the sweating surface. Haynes' stellite is slightly more sluggish in a reducing flame than in a neutral flame, but the former promotes the proper amount of surface sweating for good results and is preferable. Any scale met with or formed in the course of the work should be floated off by manipulation of the torch.

Stellite, and most of the true hard-facing alloys, can be applied to almost any steel base with the exception of high speed steel. The microstructure of low and medium carbon steels and low alloy steels is least affected by the necessary heat and the bond or adherence of the facing is probably slightly better than on high carbon steel or complex alloy steels. The structure of the latter may be altered to such an extent that heat treatment of the hard-faced part to restore the original properties of the base metal may be desirable. Oil should be used as the quenching medium because a water quench is too severe and the outer layer may check.

Hard-facing requires a special technique when applied to Hadfield's or 13% manganese steel — as, for instance, to railroad crossing inserts, steam shovel bucket teeth, or crusher jaws and liners. When this steel is heated to the welding temperature and cooled in the ordinary way, it becomes brittle. Furthermore, its coefficient of expansion is about 50% greater than that of a hard-facing alloy of Group 4. The steel may be restored to its original ductility by quenching the hard-faced part from about 1830° F. in water; however, this means of restoration — and in fact, satisfactory application of the hard-facing — cannot be accomplished unless the differential expansion is counterbalanced.

If the blowpipe is used for welding on the surface layer, the high manganese base metal is raised to a temperature almost equal to that of the hard-facing metal. Therefore it will have expanded, and will later, during cooling, have to contract some 50% more than the hard layer applied to it. This obviously will lead to deep-seated cracks, either immediately or in service. Resort is therefore had to the electric arc as a welding medium, as the momentary application of the arc on the manganese steel surface heats the surrounding steel to a considerably lower temperature than the hard-facing alloy. Under this condition its expansion effect will be under control and the stresses at a minimum.

Positive or reverse polarity is recommended for hard-facing rods applied by the electric arc. Coated rods are preferable, as they control the arc stream as well as minimize oxidation. Rods $\frac{3}{16}$ in. in diameter may take about 125 amperes, $\frac{1}{4}$-in. rods 160 amperes, and $\frac{5}{16}$-in. rods 190 amperes. Some manufacturers recommend a double layer for maximum wear — a thin undercoat which will absorb undesirable dilution from the base metal, and a thick second layer. Beads for this last layer should be $\frac{3}{4}$ to 1 in. wide and approximately $\frac{3}{16}$ in. thick.

Arc Welding Is Particularly Valuable in Welding Austenitic Steels Like Cast Manganese Steel and for Other Hard-Facing Alloys Where Heat Effect Must Be Minimized. Photo Courtesy Lincoln Electric Co.

Uses of Hard-Facings

Whereas the drilling bits for oil wells presented the best field for rapid and consistent development of hard-facing metals, and the petroleum industry consumed probably 80% of such materials prior to 1930, the situation has broadened very largely since then. At the present time the consumption in this industry represents probably less than 50% of the total. This is not due to any substantial decrease in well drilling activities, but to the adoption of the idea by other fields. Principal among these may be mentioned *(a)* the construction industry, particularly the excavators, *(b)* the automotive industry for valve seat inserts, *(c)* the cement industry for handling hot clinker, and *(d)* the metallurgical industry for coke handling equipment and hot metal shears, dies and trimmers.

A few notable applications other than for oil-well drilling bits (the application which has doubtless received the most publicity because of its spectacular success) will now be described.

First is seats for exhaust valves on heavy duty gas engines. As shown in the view on page 137, these generally consist of a steel insert ring with the hard-facing material applied to the beveled surface. The cast iron valve seats cut into the cylinder blocks of heavy duty trucks and buses must be ground about every 10,000 miles. Service tests have proved that the hard-faced valve inserts will operate for 10 to 20 times this mileage. This means lower gasoline consumption, lower compression losses, and increased power, mileage and all-around motor efficiency. One truck operator reports that no regrinding of hard-faced valves has been necessary when overhauling after runs as high as 250,000 miles.

Next example is the excavating industry, where hard-facing is used on parts ranging from the humble plowshare to the teeth of mammoth steam shovel buckets. Probably the most extensive use is for bucket teeth. A fairly typical example may be chosen from hundreds available: The teeth of a 12-yd. bucket were hard-faced by a coal company in Indiana, and achieved a life ratio of 7 to 1 over the ordinary teeth. Other types of excavating buckets such as drag line buckets and clam shell buckets, dredging cutters and drag scrapers are also very successfully protected from abrasion. *(Continued on page 144)*

HARD FACING

Similar conditions exist for coal cutters. When tipped with an ounce or two of non-ferrous alloy of Group 4 these will cut from three to six times as much as ordinary bits, and when faced with tungsten carbide particles held in a steel matrix the performance is 25 to 1 over steel bits. Since it takes about one man-hour of labor to change the cutters, this is an item even if lost machine time is disregarded.

The cement industry likewise is a large user of hard-facing material. Equipment is necessarily subjected to extreme abrasion; the raw materials, the cement clinker and even the pulverized cement all wear away the hardest steel in a very short time. Take for instance a screw conveyor as shown at the head of this article or a grinding ring for hot clinker. Tests run by an Illinois cement company showed that these hard-faced rings lasted 4640 hr. whereas other rings were unfit for service after 500 hr. Other examples of hard-facing in cement plants are gudgeons, conveyor sleeves, pulverizer hammers, roll crusher teeth, and crusher mantles.

In fact, all rock crushing equipment in mines, concentrators, gravel preparation plants, and slag crushers can use these hard materials to great advantage. The crushing surfaces are extremely massive castings, and since their life can be prolonged indefinitely by periodic applications of weld metal, the economies are apparent. A conservative estimate of the cost would be about 25% as much for hard-facing as the cost of a new part lasting only half as long.

Finally an interesting story might be told about power-plants, other than the coal and ash handling machinery. Steam valves, hard-faced, have been inspected after 14 months' service in 460 lb. steam, frequently opened and closed in a drip pot, yet showing not the slightest evidence of scoring or wire drawing. Other steel valves in comparative service will leak badly in a few months. Another interesting application is the valves on duplex boiler feed pumps. Ordinary valves in one particularly severe duty would be replaced, deeply cut, after about 500 hr. of service. In an effort to obtain longer life, the valve seats, approximately 2 in. diameter and 1/4 in. thick, were made in two sections and were covered with a thin layer of hard alloy. It was found that these valves operated for at least 4000 hr. before rebuilding was necessary.

EDITORIAL NOTE

(Continued from page 135)

now on the wane. Where conditions are really severe and the job is of considerable importance, ample experience has proven that only the best of abrasion resistors will be satisfactory, and it is poor economy to put on other alloys because they are cheaper.

Finally come the diamond substitutes, so called. They really can be compared with nothing but industrial diamonds, for, when set in the bit of a rock drill such as shown in the engraving on page 135, they go on down through the rock strata until the steel backing is gouged into deep channels, leaving the hard insets on ridges between, still taking the wear! Tungsten carbide is the foundation of the most successful of these materials. Diamond substitutes are available in various forms: As cast slugs or granules, as mixtures of finer particles and fusible metal in steel capsules, and as small pieces pressed from mixed powders of carbide and a metal binder. In all instances the pieces are set in the tool by building up a heavy layer of weld metal on the required surface and dropping these fragments into the molten puddle as it advances. Such weld metal, of course, should be hard and adapted to the work in hand.

Much attention has been given to the use of other hard artificial minerals besides the tungsten and molybdenum carbides. Fused aluminum oxide, for instance, has a very high hardness suitable for the best grinding wheels — and is, in fact, the counterpart of some of the hardest gems, short of the diamond. The element boron has also been studied. It is next to carbon in the periodic system of chemical elements, and various plausible reports of excessively hard crystals of "pure boron" have been heard. Likewise the borides of the elements could very readily have properties, like hardness, similar to the carbides.

The most recent reports from California (where the hard carbide industry flourishes — especially for well-drilling equipment) are to the effect that chromium and boron, when fused together, form a duplex aggregate, one constituent of which is possibly chromium boride and is extraordinarily hard and stable, while the other constituent may include the unavoidable impurities in the raw materials. This second constituent is "wetted" by the steel or nickel which is used for setting these chromium borides on the required surface.

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PROBLEMS & PROGRESS IN STEEL QUALITY

as it applies to producer-consumer relations

FROM A PRACTICAL AND ECONOMIC viewpoint, steel quality is that group of properties essential to the constant production of finished goods of merit, measured in terms of satisfactory service rendered at the lowest ultimate cost. In this sense it is an ever changing and a competitive standard.

When the product of the Bessemer converter first supplanted wrought iron, the new metal was just "steel"; steel quality was then supreme, no matter how far its standards may have differed from those of today. It is fitting to acknowledge with admiration the role it played in America in the conquest of the West and in the development of our industries. Not until many years later when the normally available steel supply began to approach the demands of a seemingly unlimited market, did selection of steel by grades, distinction by properties and by analysis, become a customary practice outside the tool steel maker's domain.

Steel specifications began with control of carbon ranges and were written in rather general terms. Some of them have grown into formidable documents covering a long list of chemical determinations as well as of physical standards expressed in terms of static properties, impact tests, microstructure, hardening capacity and many other specific features. There are programs today where the testing of a single set of samples, selected to represent a heat of steel, requires more than two man-months of laboratory work!

Yet in spite of diligent efforts on behalf of producer, as well as of purchaser, testing procedures frequently did not reproduce adequately the actual fabricating and service conditions, or (on the other hand) they would exclude, on theoretical grounds, material of good practical value, thus resulting in dissatisfaction and economic waste. Consequently a growing number of followers has been won to the conviction that the time has arrived for a new type of coordination between steel producers and steel fabricators, so that their combined efforts may yield a greater measure of success in the satisfactory discharge of their joint obligations to the consuming trade.

This does not mean greater tolerances or leniency in the matter of quality. Quite the contrary. It means more exacting and more consistent standards of performance to assure high yield and high quality production at low cost. In this direction the using and fabricating industry has shown the way; it has made admirable progress in recent years under the whip of active competition, through engineering skill, careful production planning, and development of shop practices.

The task now confronting the steel producer is to measure up to these standards and to furnish his products in conformity with them. To do so imposes on him a twofold obligation. First, he must organize his own resources and operations for a higher degree of effectiveness, and secondly, he must acquire

By Walther Mathesius
General Superintendent, South Works
Illinois Steel Co.
Chicago, Ill.

Notes from an address at Carnegie Institute of Technology, Pittsburgh

a direct and intimate acquaintance with the processes of his customers and with the purposes of their products. These subjects concern the entire industry — from ore and coal to coke works and blast furnaces, through steel works, rolling mills and forges, to transportation, sales and service divisions. Each unit is like a link in the chain, essential to its strength as a whole.

Let us see how they stand today.

In the coke works and blast furnaces we can confidently rely upon constant and reliable performance, proven by the eminently creditable results achieved by them during the recent lean years. These facts are so contrary to many dire prophecies and so pertinent to our problems and progress that they warrant further consideration.

Taming Temperamental Blast Furnaces

Not so many years ago, even a moderate change in coal mixture or in coking time was viewed with considerable alarm by coke plant operators and blast furnace men alike, both fearing that any departure from the empirically established normal coke plant practices might have harmful effects on quality of product and on operating costs.

That such adverse events are nowadays experienced on rare occasions only, that coke plants and blast furnaces adhere steadily to new and higher standards in quality of products and of performance in the face of presumably impossible variations in operating rates, is, in my opinion, due directly to a better understanding of the fundamental relations between cause and effect and to the skill of the operators in applying this increased knowledge to their work.

Even to a greater extent has the same diligent analysis of cause related to effect enabled the blast furnace men to achieve excellent adaptability to lower and widely varying demands with outstandingly reliable performance, good economy, and with high quality standards. Controlled production (that is, operation under satisfactorily complete technical and scientific direction) has become a fact in present-day blast furnace practice.

I should like to pause and look back 20 years or more to the time when members of the ancient and honorable blast furnace guild matched their inherited wisdom, skill and tenacity against the proverbial fickleness and cruelty of their charges. Special notices were posted (some still existing) bidding all and sundry to stay away and granting access only to the crews, the *morituri* of the industry. And these warnings were no nursery-tales as we know who lived through weeks and years of high blast pressure, hanging periods, slips, explosions and breakouts.

No wonder that blast furnace operations, notoriously unruly and obstreperous, aroused the curiosity and interest of many a man from other fields of endeavor, and that they became a favorite subject for speculative theories and visionary remedies, too often quite unhampered and unbiased by any real knowledge of the problems. And thus we find, in the period that followed, such incongruous companions as dry blast or oxygen enrichment together with practices unable to regulate and control even the rate of air supply; we see elaborate automatic charging machinery designed to achieve the utmost in economy and uniformity, while ores continued to range in size from a fineness suitable for milady's rouge to boulders weighing tons.

But quietly and steadily we pursued our search for the real causes of our troubles. We adapted facilities and practices to the changed nature of our raw materials, the soft, fine Mesaba ores and the smaller, more open-structured, more friable by-product coke. We learned to grade our materials for constant physical and chemical properties, we redesigned and strengthened our equipment, to provide additional security and smooth, uninterrupted performance. In short, we adopted the tactics of the Chinese doctor, who, we are told, was paid to keep his patients well and who forfeited his fee when he failed to do so. And our blast furnace patients have responded nicely to this treatment — thank you — they are quite well today, with youthful strength and vigor, confident of their power to more than hold their own against such upstarts as the direct reduction processes, of which we have heard a good deal in recent years.

Refining of Modern Steels

Turning now to the steel melting departments, it appears that intermittent operations during the past few years have been a severe handicap to the systematic scientific study of processes and reactions.

Our steel-making shops possess a certain degree of adaptability to varying demands, being able to add to or subtract from the number of active units. But each furnace or vessel is, in itself, rather inflexible because good results in quality depend upon adherence to definite operating cycles. Intermittent performance is, as a

rule, accompanied by serious deterioration of refractories and other equipment. To this must be added the difficulty of arranging for effective organizations under part-time employment and work sharing rules, where a majority of the crews possess years of training in a few specific duties and where the possible interchange of occupations is therefore limited.

In the light of such difficult experiences which have been keenly felt at most plants, steel works operators are beginning to recognize more generally that the empiric rule of thumb is a poor second to carefully planned and executed process control, based on a thorough understanding of the pertinent fundamental facts. There is still much work to be done, however, by qualified engineers and operators, before this knowledge may become the common law, so that steel melting practice, the skilled art of today, may be a science tomorrow.

Fortunately, as is the case with most general rules and statements, there are exceptions to this one also. Recent developments in the production and conversion of stainless steels may serve as an interesting example in point.

It was just a few years ago that we first dared to take these bright youngsters of our steel family out of the nurseries — the laboratories and the specialty shops. Training them toward usefulness on a broader scale, with volume production, has imposed on the steel producers many novel, interesting, and difficult problems. The prompt and successful solution of these must, in my opinion, be primarily credited to the fact that here production was developed from the very beginning under the direct guidance of concurrent scientific research. Thus progress was made logically, limitations in properties of the various grades were established, and operating practices were adjusted. We have succeeded in meeting a wide range of demands in stainless steels, from the finest wire and hypodermic needles to massive ingots weighing 60,000 lb. and more (which have been forged successfully, as well as rolled into many classes of products — for instance, strip and plate of over 6 ft. in width and hundreds of feet in length).

Let us return now to the production of the more common varieties in steel and note that here too progress has indeed been made during recent years. More recognition has been given to the importance of quality in finished products at low cost and to the necessity of subordinating to this standard every single step of departmental performance. This has led to many improvements in the practices of making suitable deoxidizing and alloying additions, closer control of tapping and pouring temperatures, and to useful studies concerning such factors as ingot size, cooling rates, and heating cycles in relation to hot working properties and rolling mill results. The gratifying progress made, for instance, of late in the production and the quality of rimming steels should be credited largely to these endeavors.

Still more must be accomplished and at a more rapid rate if production in alloy and forg-

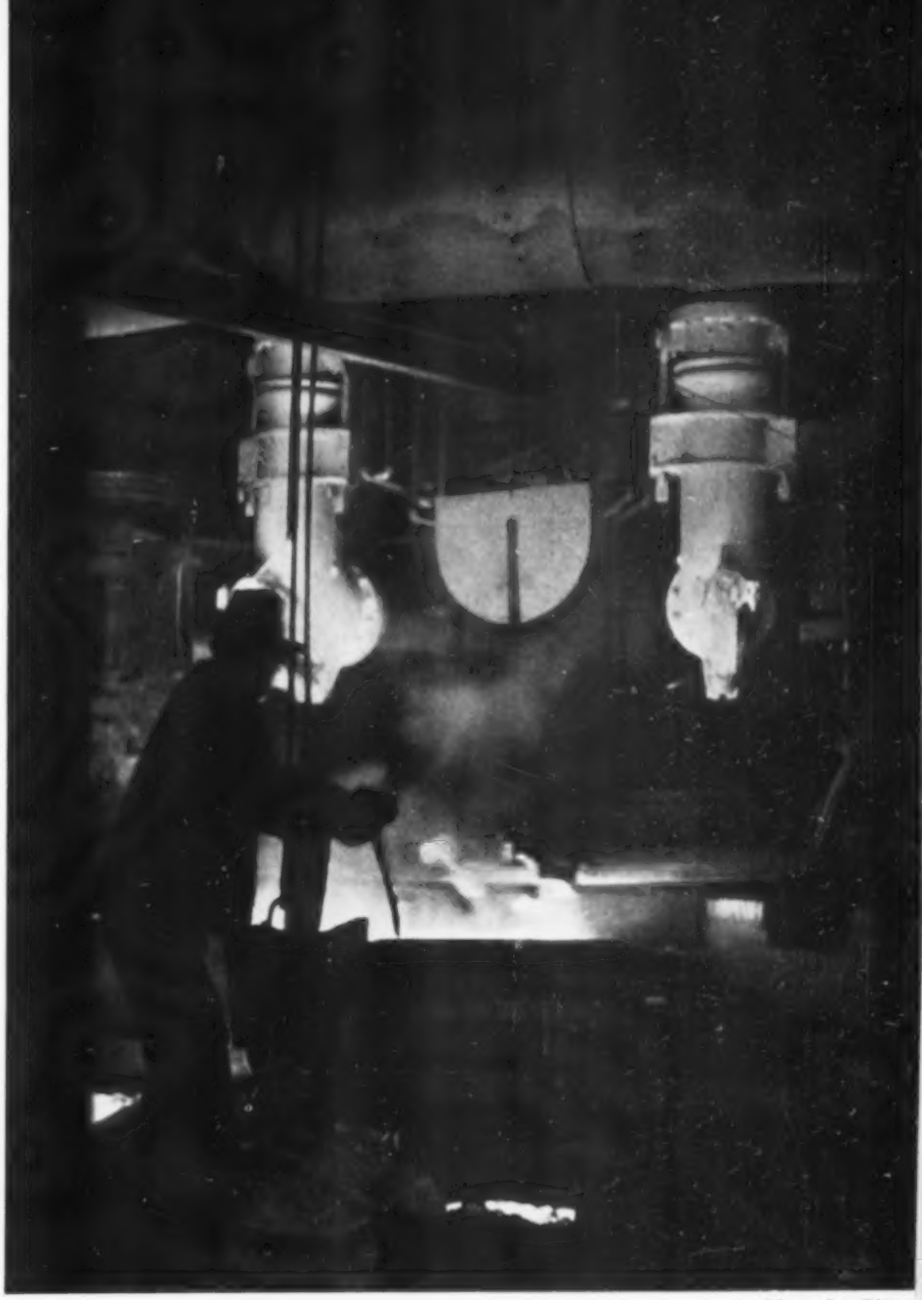


Photo by Rittas

". . . . . Members of The Ancient and Honorable Blast Furnace Guild Matched Their Inherited Wisdom, Skill and Tenacity Against the Proverbial Fickleness of Their Charges . . . . ."

levels of investment charges and operating costs incurred in a race for favorable consideration by customers in a declining market. Aside from these problems of management and finance, it is strange that the rolling mills have received a comparatively modest share of attention from engineers, metallurgists and technically minded economists. Even some of our most recently created rolling mill marvels seem to lack that moving spirit which applies expert knowledge and logic in place of tradition and precedent.

Just consider the wide variety of technical subjects currently encountered, such as problems of combustion and of heat transfer, of steel properties in many grades and under widely differing conditions of temperature and stress, of power requirements, lubrication and machine or roll design! Add to this the perception of the marked influences exerted by rolling mill practices and cooling rates upon the properties of products, on which in turn depends their usefulness in subsequent fabrication or in service — and we may conclude indeed that new thought, new problems, new products and new steels demand a new spirit and new blood among the thinkers and the toilers of the rolling mills that they may carry on and succeed in this, the hardest economic struggle of our generation.

Photo by Rittase

". . . . . Steel Producers and Their Metallurgists Took the Lead and Developed the Thoroughly Killed, Fine Grained, Aluminum Treated Steels Giving Great Promise . . . . ."

ing steels, as well as in the so-called ordinary tonnage grades, is to keep pace with the quality demanded. Ability to control and to reproduce regularly definite grain size and quench-hardening characteristics, or cold rolling and cold forming, non-aging, welding, enameling, galvanizing and tinning properties, or impact and fatigue resistance, microscopic cleanliness, machining ease and smoothness of finish, hardness, depth and resistance to spalling after case carburizing, or uniform soundness, strength and toughness in rails and structural shapes — all such topics are related to and dependent upon process control in steel making.

A word now about the rolling mills:

Many of their recent trials are probably due to extraordinary practices and to impossible

Knowledge About User's Problems

We shall now consider the steel producer's second task. To achieve real progress in steel quality, he must acquire a first-hand knowledge concerning the behavior of steel products during subsequent fabricating operations and in ultimate service. The successful steel plant manager can no longer consider his responsibility for quality discharged by having a fair proportion of his output conform to the inspector's often changing ideas of acceptance standards. He must train his staff and direct its work throughout the entire plant, that the products will continuously suit the fabricator's processes and will permit the latter — with due care and intelligence on his part — to turn out a satisfactory finished job with a minimum of rejections and at the lowest over-all cost compatible with service requirements.

It is certainly no simple task to subordinate every point of departmental advantage and pride

to the final joint obligation. It requires the development of a broader view in every branch of the organization. The functions of the present-day steel works' metallurgist may serve as an example in point. No longer can he confine himself to process control in the interest of operating economy. It now becomes his task to analyze quality requirements in advance of production, to contact customers regularly and frequently, so that he may effectively assist in formulating the manufacturing program of producer and of fabricator for the best of coordination and of combined results.

It would, no doubt, have been an extremely difficult undertaking for the average process metallurgist to effect this adjustment had he not received merely for the asking the whole-hearted cooperation of his fellow worker, the product metallurgist on the fabricator's staff. I should like to give credit especially to the automotive industry for having been among the first of the major steel users to recognize the inherent deficiencies in the older methods of dealing in rigid and detailed specifications and for having lent a capable and helping hand to bring about the more direct contact and understanding of technical requirements, which has enabled the steel industry to satisfy the many exacting and often rapidly changing demands of the motor world.

Recognizing this, the steel producers are now learning to conduct their operations "salesmindedly" and to judge the merits of their products by these three major considerations:

1. Service rendered in ultimate use.
2. Behavior in fabrication.
3. Steel making and conversion requirements.

Many examples may be selected to illustrate more clearly the principle under discussion. We might cite, for instance, the fact that one chromium-vanadium steel (S.A.E. 6150) when supplied for transmission gears is judged primarily by its microscopic cleanliness and its uniform response to a specific annealing cycle, to assure accuracy and good tool life. Again in the same steel, when supplied for springs, the size, straightness, uniformly moderate hardness and smooth surface of the hot rolled bars are ruling considerations, and when used for automatic machine work correct microstructure and freedom from internal strain. The extent to which these features are controlled by the steel producer within satisfactory limits becomes the specific commercial index of his performance standard.

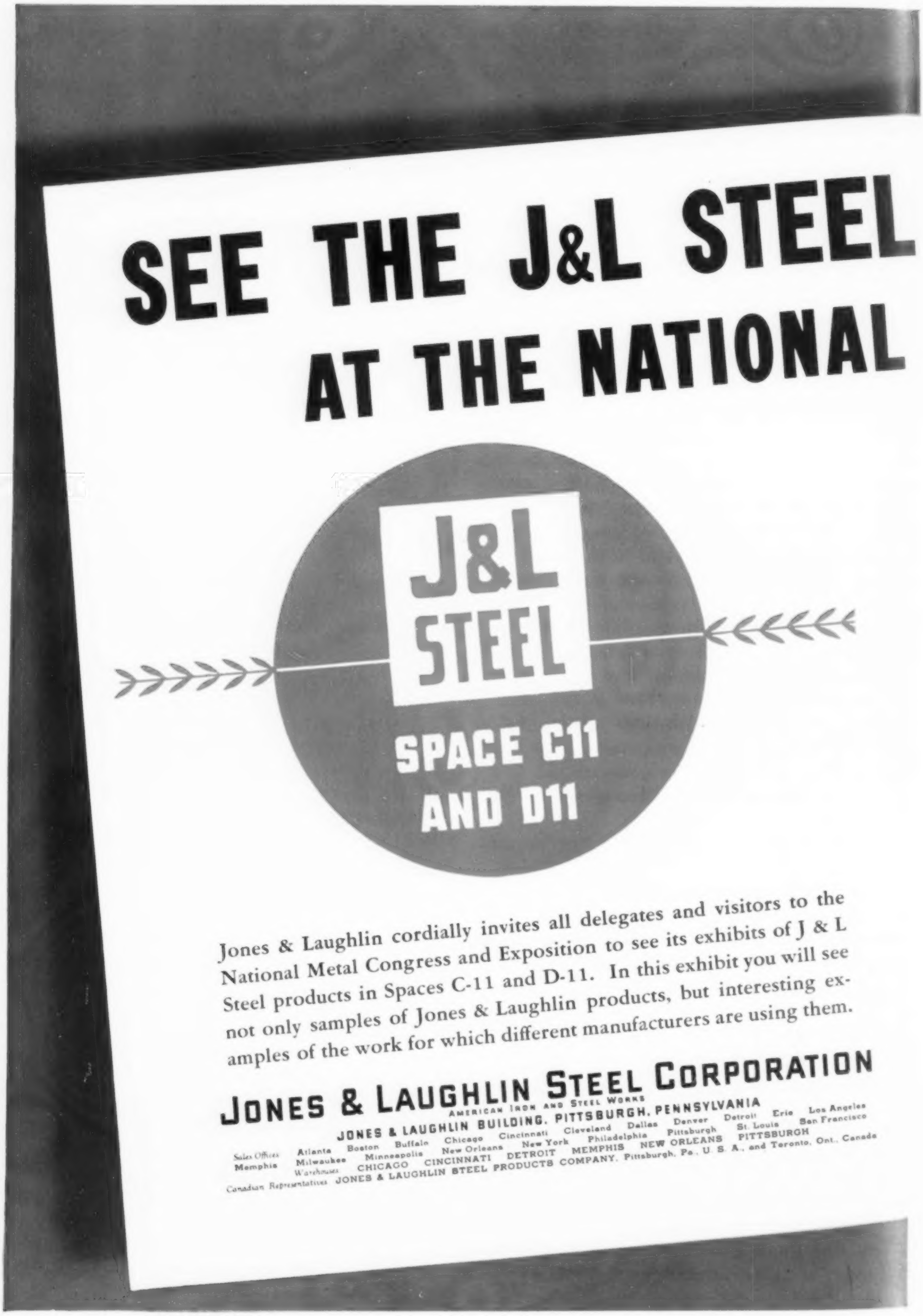
Another example in point, and one requiring large tonnages today with increasing demands in sight, pertains to "ordinary" low and medium carbon steels in the form of plates, sheets and strip, suitable for severe cold forming operations. Frequently other fabricating requirements such as welding, enameling or galvanizing, or other desired properties like corrosion resistance, nonaging and high strength characteristics add zest to the game and challenge the ingenuity of the producer. Here each new design of parts, each new forming process, may it involve automobile brake drums, fenders, and chassis frames, or grave vaults, furniture and corrugated culverts, or hydraulic penstocks and welded pressure vessels may require individual study for each step of production right back to the open-hearth furnace and beyond.

Selection of Carbon Steels

While for all of them steel is used within a narrow range of specifications in terms of ordinary carbon steel chemistry, success depends on the selection of the correct physical type from the many classes of rimmed, semi-open, and killed steel grades.

Present-day economic demands cannot afford to tolerate the excess cost and the waste of extra weight and high safety factors whereby allowances were made in the past for inferior or irregular quality features. This is quite clearly brought out in the demands made by the fabricators upon steel producers in connection with the use of structural materials and plates in steels of higher tensile strength. Apparently the principal points of distinction over the usual ordinary steels are related to chemical composition, the addition of alloys and their effect upon physical properties. Actually, these new commodities must be furnished to much more exacting standards of constancy, soundness and reliability. These are the features which require more accurate manufacturing control, limit the yield of acceptable product and increase the production cost. In comparison, the changes in steel chemistry are often a minor consideration, especially if judged by the mere cost of the alloys used.

The same trends are apparent in the field of low carbon sheets and strip steels, where excellence of surface and cold forming properties are the outstanding features. For many years, a normal, well made, semi-killed steel, containing small amounts of silicon, answered most of the requirements of this trade. But as forming practices became more drastic *(Cont. on page 158)*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NOW MADE FROM Cold Drawn Steel . . . .

THIS PART COSTS 13¢ LESS

Formerly made from a casting, this spindle is now manufactured at less cost and with greater strength from a $2\frac{1}{16}$-inch round cold drawn steel bar. It is tapered to approximately $1\frac{1}{4}$ inches

● Here is an interesting outcome of the search of a progressive manufacturer for new economies. The part illustrated naturally suggests the use of castings and for years it was made by that method. Then Union Cold Drawn Steel was investigated, despite the fact that the obvious waste of metal and required amount of machining argued against any possible savings. Trial showed, however, that costs were materially reduced, due largely to the exceptional machinability of cold drawn steel.

Union Cold Drawn Steel opens up many avenues for savings because of its pronounced machinability, its smooth, bright surface, its high degree of accuracy, its marked uniformity and its extensive variety of shapes and sizes. It provides distinct superiorities in physical properties over hot rolled bars, iron castings, steel castings and forgings. It promotes the most efficient operation of automatic screw machines.

Even though cold drawn steel may at first appear impractical for many applications, don't pass judgment without a thorough investigation. It has a great deal to offer and its field is widening day by day.

UNION DRAWN STEEL CO. MASSILLON, OHIO

SUBSIDIARY OF REPUBLIC STEEL CORPORATION

Cold Drawing
PROVIDES MAXIMUM MACHINABILITY

Union
SPECIAL FINISH
COMBINES GOOD APPEARANCE WITH EXTREME ACCURACY

● The ground and polished surface of these small diameter bars adds beauty to the design of modern machines. Their finish is excellent for nickel or chrome plating. Just the thing for exposed shafts or other uses, particularly where straightness, concentricity, precision in size and improved mechanical strength are desired.

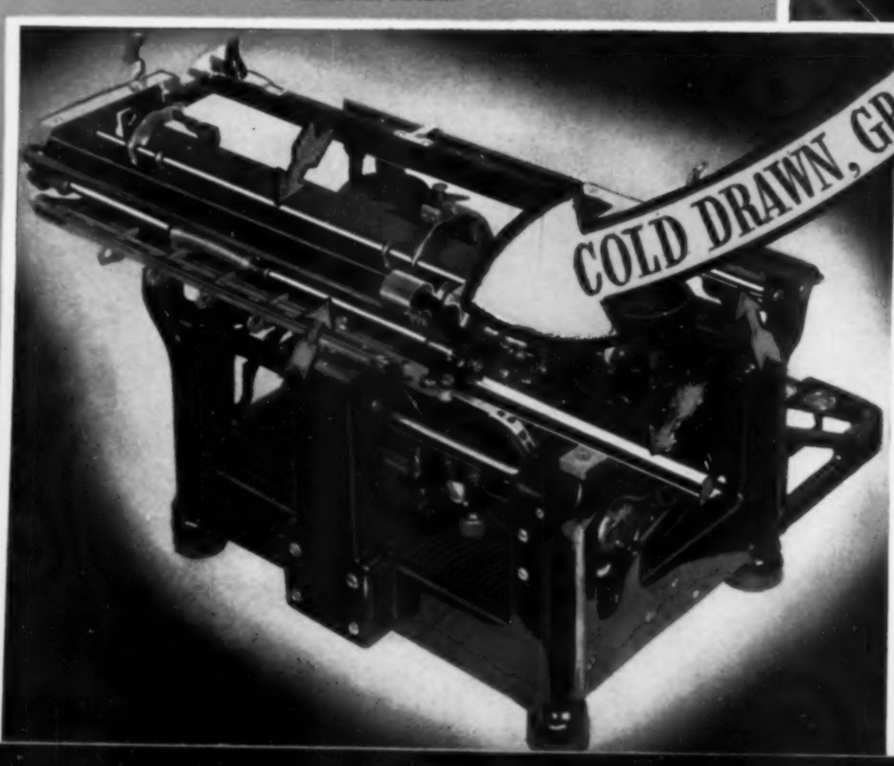
You can secure Union Special Finish of any carbon or alloy steel grade, in short pieces or long bars and in all fractional sizes from 1/8 in. to 1 1/8 in. inclusive. The commercial tolerance is exact size to minus .002". Closer tolerances — exact to within a total of .0005", or exact to .00025" under on standard sizes only — can be furnished on special order.

The illustrations on this page indicate many types of applications. They will likely suggest similar profitable uses in your production.

We also furnish cold drawn flats, squares and special shapes of all sizes with ground and polished finish on one or more flat surfaces.

UNION DRAWN STEEL CO. MASSILLON, OHIO

SUBSIDIARY OF REPUBLIC STEEL CORPORATION



Union Cold Drawn Steels

STEEL QUALITY

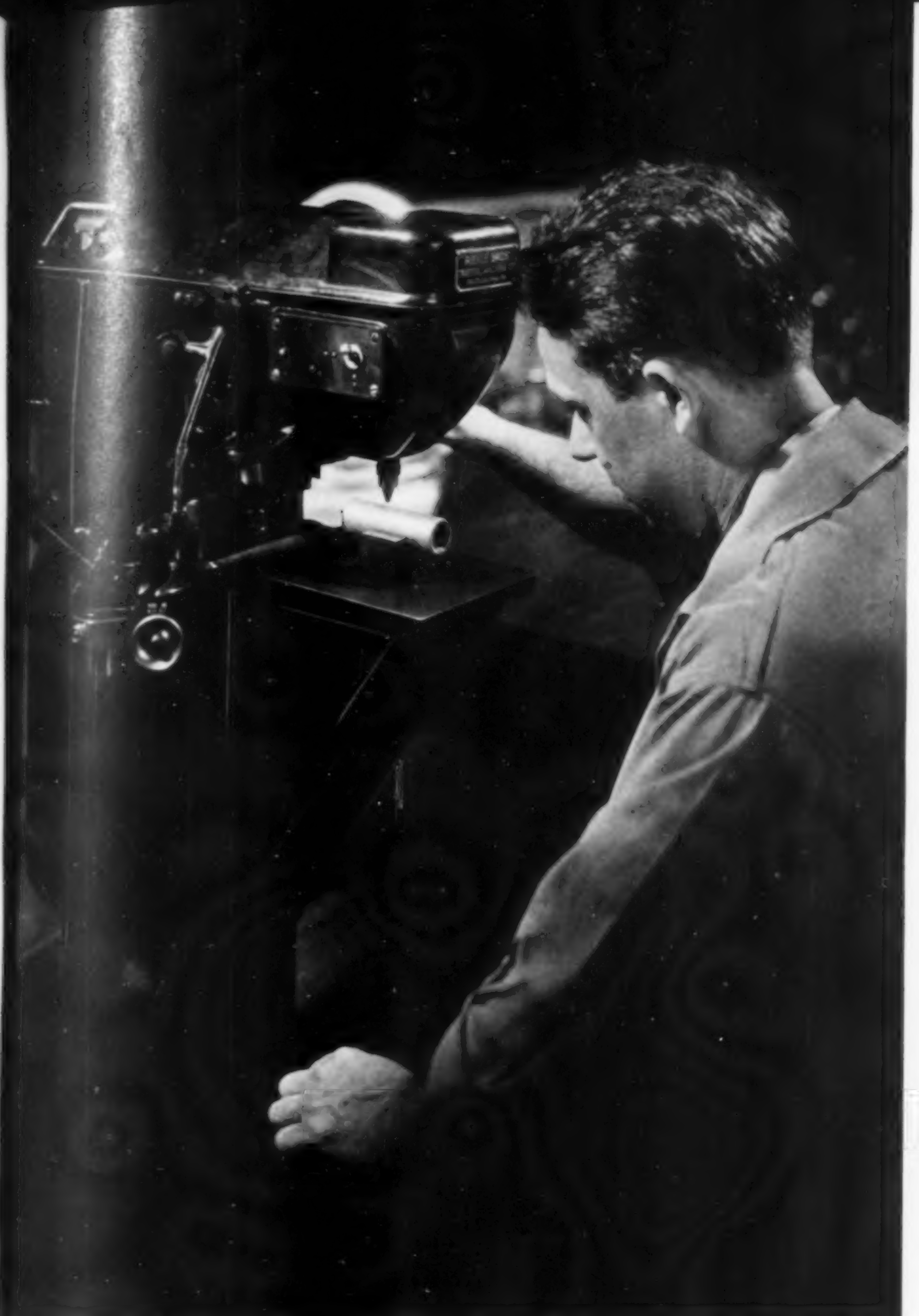
(Continued from page 153) and three-step deep drawing went to two-step and single operations, greater ductility and greater uniformity were demanded than could be produced in this steel.

Rimmed steels became the vogue with little, if any, change in chemistry, but with a decided improvement in ductility and lower work hardening effect. It soon became apparent, however, that this type was not the panacea which the sheet mill and its customers were seeking. It has brought about splendid improvements in many applications, but plenty of disappointments in other lines. Due to its inherent nature, related to the deliberately promoted selective freezing process of the steel in the ingot molds and its typical array of blow holes, it has caused troubles through non-uniformity of properties between different sections of product, corresponding to the inner and outer portions of the ingot as cast. The blow holes gave rise to blisters in severe pickling, such as that used in preparation for galvanizing, and matters grew worse when certain welding practices and enameling processes had to be considered, not to mention the serious complications which arose from the age hardening tendencies of the rimmed steels.

As a result we find another instance where the steel producers and their metallurgists took the lead and succeeded in developing a series of thoroughly killed, fine grained, aluminum treated steels, which give great promise of a decided step ahead, since they combine in a large measure the desirable properties of the rimmed and the silicon-killed types, without inheriting their principal limitations.

I venture to hope and to predict that, with the return of faith in our economic future, we will soon confront a larger volume of production and that, with this, we will face new quality requirements, new steel grades, new uses, new problems.

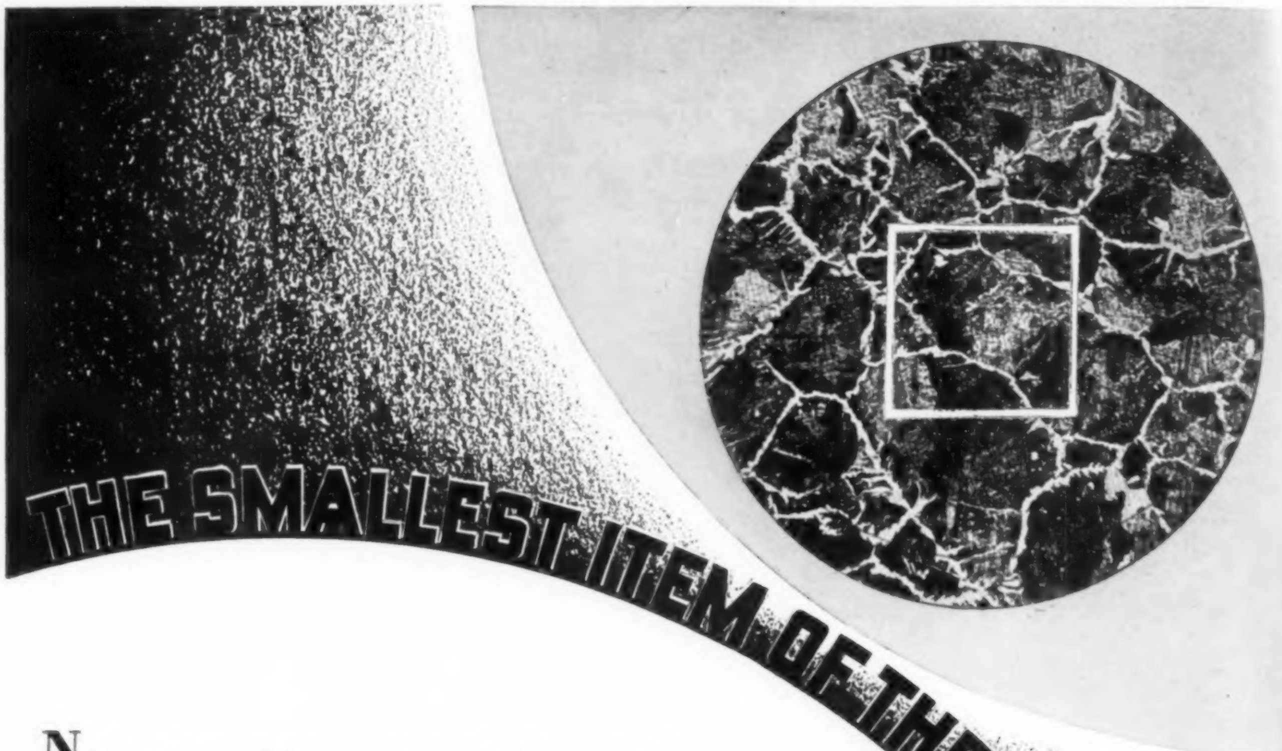
We shall welcome them and meet them with a new willingness to understand, a new resolve to cooperate throughout the many phases of processing, fabricating and service. By searching for and finding the cause for each effect, by welding our data into a solid chain of logical evidence, by applying the inevitable conclusions to production and to development, we shall achieve progress in steel quality.



y Republic Steel Corp.

INSTRUMENTS FOR TESTING & CONTROL

A Glance at a Pioneer's Testing Instruments, Two Centuries Back, Shows the Remarkable Progress in Intervening Years. . . . . . Much Testing, X-Ray and Otherwise, Is Now Being Done at Elevated Temperatures. . . . . . And Accurate Temperature Measurement, Including Pyrometer Calibration, Is Essential



NOW, with the B & L new Grain Size Measuring Eyepiece (suggested by Dr. Marcus Grossman) determination of grain size becomes a simple routine procedure which rapidly produces accurate results. It is well worth coming to the show to see.

But this eyepiece is the smallest item in the entire B & L Exhibit. Other instruments of far greater importance will be shown. Here is a list of them.

The photomicrograph (above) represents the view seen through the eyepiece (below).

*Ortho-Stereo Camera	*Shop Microscope
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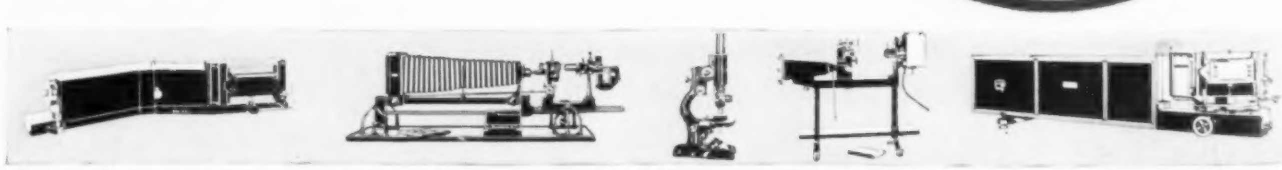


Medium Spectrograph, Large Metallographic Equipment, FSM Microscope, SI Metallographic Equipment, Littrow Spectrograph

TESTING AND CONTROL INSTRUMENTS OF 200 YEARS AGO

IN 1683, IN THE FRENCH CITY OF LA Rochelle, there was born Réné Antoine Ferchault de Réaumur, who grew up to be "an open-eyed naturalist, and as diligent and accurate an observer as ever lived." His investigations and achievements were so varied and numerous that the modern specialist is put to shame. He devised a system of thermometry which is still known by his name; he studied the formation of pearls, and of the scales of fish; he suggested the use of wood fiber for making paper; his six-volume Histoire des Insectes is still a rich mine of information for entomologists; he wrote a treatise on the arts and crafts of France; he studied the manufacture of porcelain; he introduced tin plate into his native land.

It seems only to be expected that so versatile a genius should have been attracted to some of the metallurgical problems of his day. Such was indeed true, for in 1722, he published in Paris a large book of 566 pages and 17 plates entitled, The Art of Converting Wrought Iron Into Steel, and the Art of Softening Cast Iron, or of Making Articles of Cast Iron as Perfect as of Forged Iron. This book, in the words of a biographer, "made known new processes for the working of iron and for the manufacture of steel which brought about quite a revolution." Harry Brearley, one of the most eminent English steel metallurgists, has written that "Réaumur may be regarded as the originator of cast steel, though his process was superseded by that of Huntsman, who 20 years later — in 1740 — introduced the practice of melting cemented bar iron. To Réaumur's credit, however, it should be said that his earlier process — the melting of wrought iron with some carburizing material — is now by far the most commonly used method of producing crucible cast steel."

By Bernard Collitt
Metallurgist
Jenkins Bros., Ltd.
Montreal, P. Q. Canada

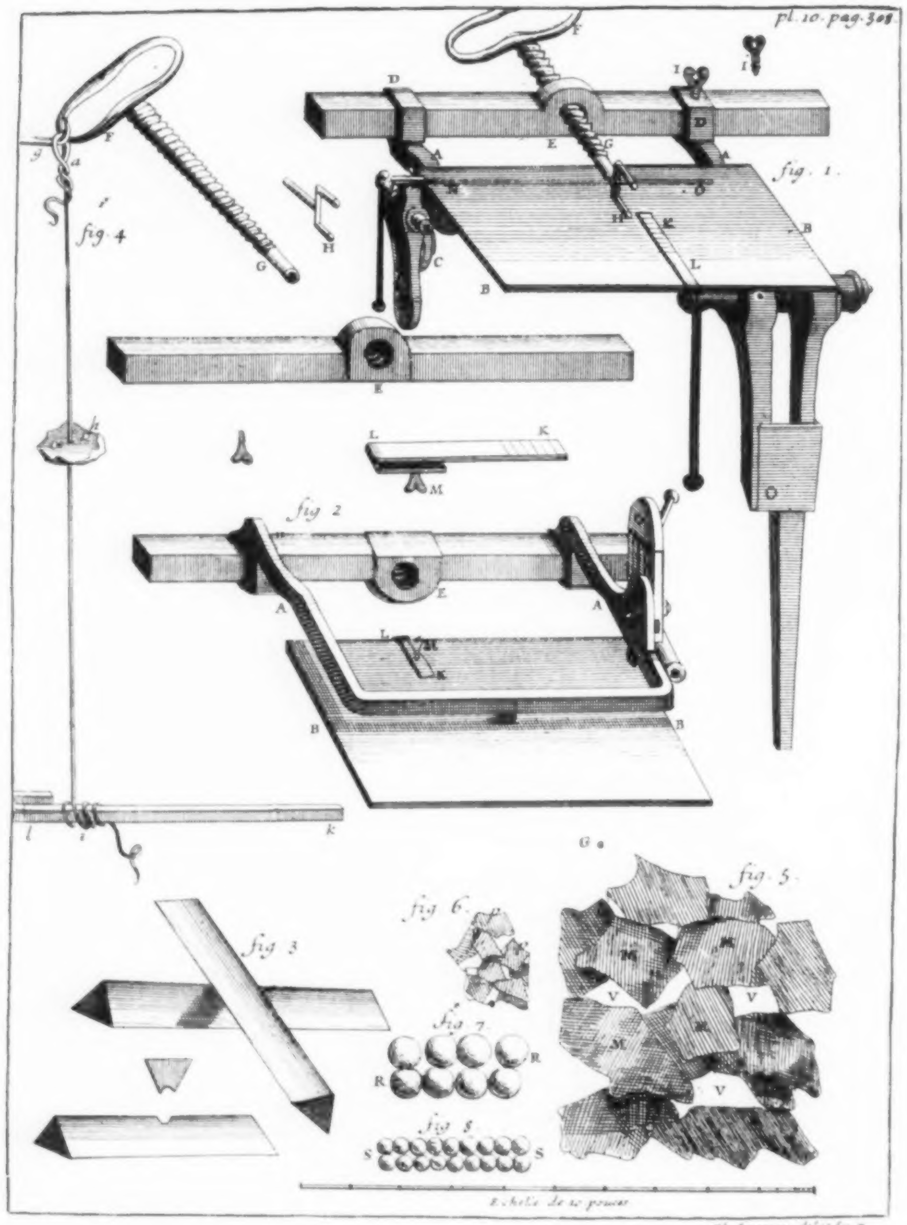
Réaumur's way of making malleable iron castings is still used extensively in Europe, where it is known as the Réaumur or white-heart process.

A diligent and accurate experimenter would certainly want to know something of the properties of his product, so Réaumur made use of the testing and control apparatus shown in the illustration on the next page, which is reproduced from Plate X of his book whose title is given above. From the context it appears that he tested his steel for hardness, tensile strength, and for "body."

In Fig. 3, in the lower left corner of the plate is represented the hardness test; in this triangular prisms of two different steels were placed edge to edge at right angles as shown. The flat surface of the upper prism was then struck, either by a hammer, or by a weight falling from a constant height. The indentations on the edges of the prisms were compared; the smaller the indentation the harder the steel. The sketch shows two steels of equal hardness.

Figure 1 on the extreme left, shows the tensile testing appliance; the test piece, in the form of wire or a thin rod, is secured at the upper end on a fixed support (shown as a stout hook *g*) and the stress applied at the lower end by loading the lever *l-k* at the end *k* on the right.

The interesting point about this apparatus is the metal saucer supported at the middle of the test piece. This saucer contained a few pieces of glowing charcoal to heat



In 1722 Réaumur Had a Good Idea of the Microstructure of Steel, Had Measured Hardness by Mutual Indentation, and Had Made Tension Tests at Elevated Temperatures

up this portion of the test piece to the temperature "necessary for it to take the quench" — in other words, to the critical range. Tensile testing of steel at elevated temperatures, therefore, was carried on over 200 years ago!

The remaining apparatus shown in Fig. 1, is that for estimating the "body" of steel, and several of the parts of the machine are depicted separately. The steel bar or rod *N-O* to be tested was fixed in the vise *C* and loaded as a cantilever by the action of the screw *F*. The stress applied was not measured, but the deflection of the test piece up to the time of fracture was measured on the scale *K-L*.

Figures 5 and 6 represent the structure, as imagined by Réaumur, of a grain of steel "prodigiously magnified." *M, M* are the molecules of which the steel is composed, *V, V* are voids. Many a metallurgist since Réaumur's time has been compelled, as he was, to reduce the section of his test pieces until they could be broken by the apparatus available, and many a metallographer has repeated what Réaumur wrote: "These lamellae should be viewed through a much more powerful microscope."

Casual glances through the following pages will show what progress has been made in this branch of physical metallurgy since 1722, nearly all of it in the life time of some men still with us. Fortunate are we in these days to be provided with machines, apparatus and instruments of such capacity, utility and accuracy.

X-RAY EQUIPMENT FOR STUDYING METAL AT HIGH TEMPERATURES

IN OUR RESEARCH WORK ON VARIOUS problems connected with the rapid and efficient production of hot rolled and cold rolled strip, we have had particular occasion to study such matters as preferred orientation and directional properties of sheet metal, rolled in various ways. In such work the X-ray is of course invaluable, if, indeed, not indispensable. In an article in METAL PROGRESS in November, 1932, I have already attempted to give the elements of X-ray technique applicable to this problem and the conclusions that may be drawn therefrom.

No large departure from standardized equipment is necessary if one X-rays metals at room temperature. However, we were led to investigate the cause of some curious results discovered in metal after rolling at temperatures near the critical range in carbon steels. This immediately required some X-ray patterns made when the metal was red hot.

Research involving X-ray diffraction from metals at elevated temperatures has always been difficult. The reason for this lies in the construction of the cassette itself (the cassette being essentially a specimen and plate holder), since it has previously been necessary to place the X-ray film on the inside of this cassette or camera. When operating such cassettes for high temperature research, they must be either evacuated or filled with a neutral or reducing atmosphere to prevent oxidation of the specimen. After the X-ray exposure is completed, the film must of course be removed from the cassette to develop it, and to do this the specimen must be cooled to room temperature and the vacuum or gas seal broken.

By Norman P. Goss
Research Department
Cold Metal Process Co.
Youngstown, Ohio

This drawback in the construction of the apparatus made it impossible to take a progressive series of X-ray diffraction patterns at various temperatures, and thus follow the changes occurring in the crystal structure. Obviously, a study of this kind cannot be made if, after each exposure, the specimen must be cooled to room temperature. If the specimen is disturbed after each exposure, it is impossible to replace it in the cassette so the X-ray beam will pass through exactly the same point as formerly — yet to get valuable results one must follow the structural changes occurring at a given point within the specimen, which should not be changed during the entire investigation.

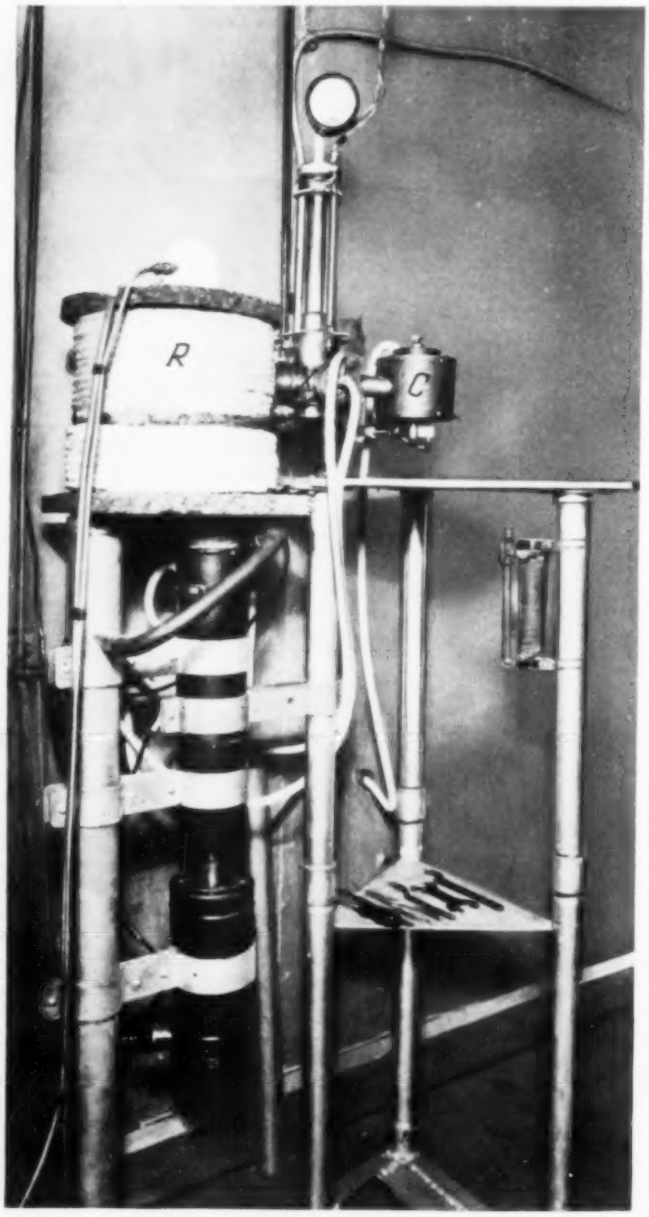
Improvements in Apparatus

These difficulties have been surmounted in our new type of diffraction cassette, or specimen and film holder, designed primarily for high temperature work, and constructed on an entirely new principle. The photograph on the next page shows the entire equipment, the cassette *C* attached to a metal X-ray tube *X*, and the refrigerating system *R*.

The equipment consists of a metal X-ray tube built in our shop of 14% chromium steel. It has a water cooled, copper target electrode to which a molybdenum button is attached. The tube is evacuated with a Gaede pump backed by a hyper-vac pump. A refrigeration

unit *R* is used between tube at right and pumps below to prevent the mercury vapor from diffusing over into the X-ray tube and impairing the vacuum.

The tube is operated at 35,000 volts and 50 milliamperes. This assures an intense X-ray beam. The beam is defined by a series of diaphragms, the first one being only 0.1 in. from the target focal spot. The X-ray beam is nearly parallel by the time it reaches the specimen in the high temperature camera.



Equipment for X-Ray Radiography of Metal at High Temperatures and in Controlled Atmospheres or in Vacuum. C is the air-tight cassette which holds the wire or ribbon along its vertical axis. X is the X-ray tube. A refrigerating system R is between the tube and above the gas pumps. The metal specimen is heated by passing an electric current through it, and the film is wrapped outside the cassette

The specimen in the form of a wire or ribbon is placed in the center of the cylinder chamber by affixing it to appropriate terminals in the top and bottom head. The cylinder itself is made of bakelite tubing, with a wall thickness of 0.06 in., which permits the diffracted K-radiation emitted from a molybdenum target to pass through freely with very little absorption. On the other hand, the undesirable scattered radiation is completely absorbed by the bakelite and clear X-ray patterns are therefore obtained even after long exposures.

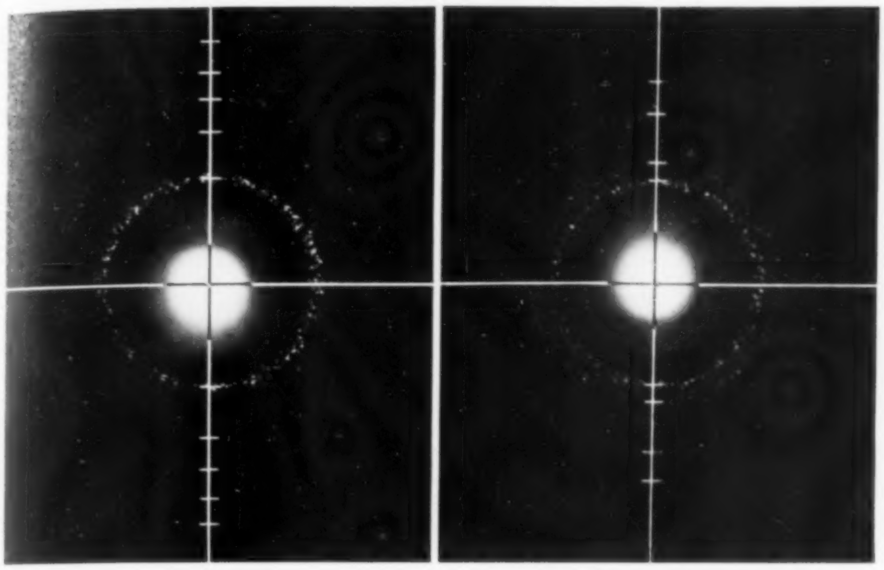
Film Outside of Specimen Holder

The film, in a light-tight envelope, is merely wrapped around the outside of the cylinder with its center near the axis of the beam of X-rays and held in place by a rubber band. Good diffraction patterns can be made in 10 to 15 min. when an intense X-ray beam is used. The resulting patterns are not systems of concentric circles, as would be the case if the film were flat and at right angles to the beam, but are ovals. Measurements are made along the minor axis of these ovals, the same as films made in circular cassettes according to Hull's method.

The upper and lower fixtures, holding the specimen, are also used to lead a controlled electric current through it, heating it by resistance to any desired temperature. To prevent overheating the bakelite by the specimen, the tube should be at least 5 in. diameter, and the specimen should be kept as small as possible in cross-section. When these precautions are taken the specimen may be heated as high as 2300° F. without damage to the cassette.

The temperature of the specimen is observed through a thin glass window mounted on the bakelite tube, and measured with an optical pyrometer for temperatures above 1300° F. There is available in this laboratory an optical pyrometer which has been calibrated very accurately for temperatures above 1300° F., and which is checked by a fixed point at frequent intervals. No corrections have been found necessary for absorption by the glass window. For temperature readings below 1300° F., other methods must be used, such as welding of fine thermocouple wires to the specimen near the intersection with the X-ray beam. So far we have been interested principally in temperatures high enough to be measured optically.

There is nothing novel about the construction of the pin-hole system, except that it must



Alpha at 1350° F. Gamma at 1450° F.

X-Ray Diffraction Patterns of 0.10% Carbon Strip Steel. Scales have been superposed to show radii of principal lines due to alpha and gamma iron respectively

be air-tight. Pin-hole systems have been amply described in the literature.

Some Resulting Films

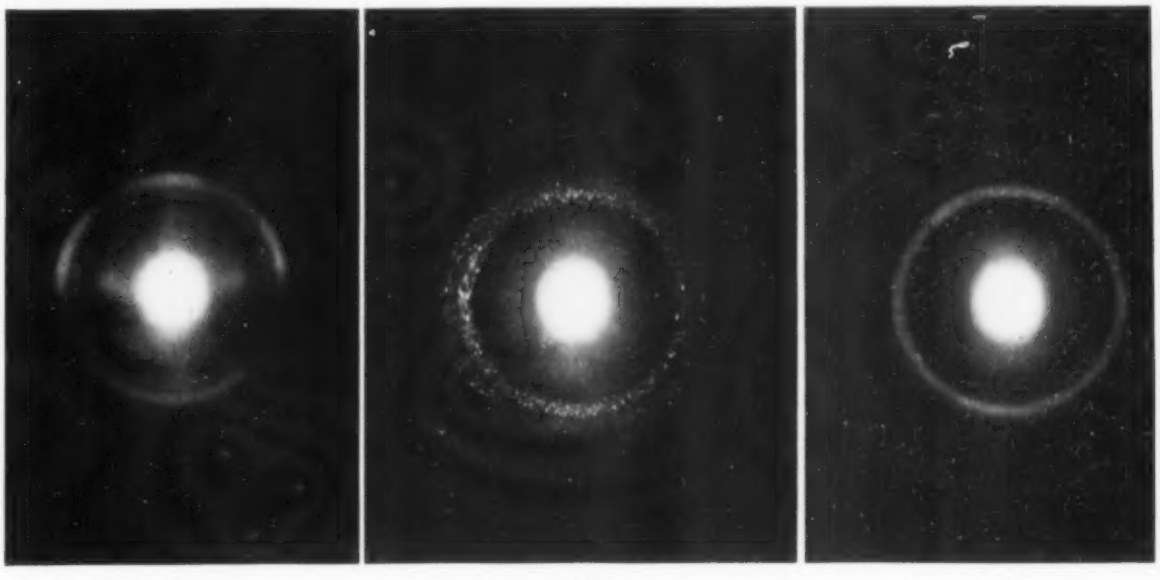
It is hardly necessary to dwell upon the possibilities of this new device for metallurgical researches. More fundamental knowledge concerning the structural changes occurring in metals and alloys should ensue when specimens are studied, step by step, while gradually varying the temperature. Such investigations are not only of theoretical importance but of technical value as well. More should be known about the structure and constitution of metals and alloys in the higher temperature ranges.

To show in a general way what one can expect from investigations of this kind, a few X-ray diffraction patterns will be presented, illustrating the effect of temperature on the crystal structure of some important commercial alloys.

The pair above is of 0.10% carbon strip steel, a commercial hot rolled strip, 0.001 in. thick. The left-hand film was taken while the metal was held at 1350° F. — that is, quite close to the A_1 temperature. To prevent oxidation a slightly reducing atmosphere was maintained in the cassette. As shown by the distribution of the reflections, the crystalline grains are uniform in size, are oriented entirely at random, and the lattice is characteristic of alpha iron. In other words, this cold rolled strip, even when very thin, has little trace of preferred orientation when heated to the A_1 transformation.

Lines are shown on these two diagrams indicating the theoretical radii for reflections (on a cassette of this size, using K-radiation from a molybdenum target) for alpha and gamma iron, respectively. These will enable a reader not thoroughly familiar with X-ray spectrography to differentiate between the two patterns readily.

Without disturbing this set-up, the temperature of the specimen was increased to 1450° F. and another film exposed — the right-hand one. This one is characteristic of gamma iron and is a rather unexpected result. This temperature is about midway between A_1 and A_3 for 0.10% carbon steel, and one would think that the structure should consist essentially of alpha iron, mixed



At 70° F. At 1480° F. After Cooling

Diffraction Patterns of 12% Chromium Steel Strip, Showing Transformation to Gamma Iron and Recrystallization on Cooling

with a smaller amount of austenite (carbide in solution in gamma iron).

The general appearance of the pattern is strikingly similar to the first one. The metallic grains are uniform in size and oriented at random. The transformation, therefore, did not change the grain size or the distribution — a fact of importance, metallurgically.

In order to check the experimental procedure against results established by Dr. Westgren, the same tests were duplicated on a ribbon of electrolytic iron. At 1450° F. the structure remained entirely alpha iron, which is in agreement with Westgren's findings, and is in accord with the accepted iron-carbon diagram.

It is suggested that the apparent anomaly in the structure of low carbon steel at 1450° is due to the fact that small amounts of impurities existing in commercial carbon steel have a very large influence on changing the lattice structure in the temperature range between A_1 and A_3.

Changes in Chromium Steel

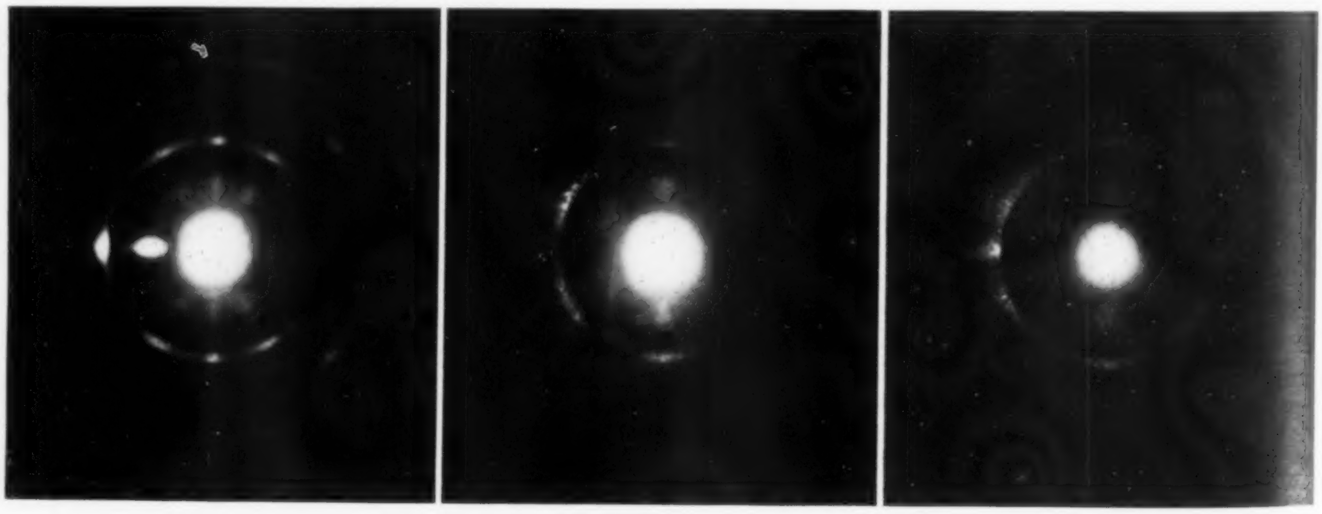
The second group on the preceding page was taken of a 12% chromium steel strip, 0.002 in. thick. The first one, at left, was exposed at room temperature; it is characteristic of alpha iron. The grain size of this material has been refined by cold rolling.

When the strip is heated to 1480° F. the lattice, as shown in the middle radiograph, changes over to the face-centered cubic, characteristic of gamma iron. This is in general agreement with the structural diagram for the 12% chromium-iron alloys given by Dr. Krivobok in The Book of Stainless Steels, second edition, page 29, which shows a temperature interval starting at 800° C. (1475° F.) where cementite, alpha solution and gamma solution co-exist. It is obvious, also, that the material has recrystallized.

When the temperature of the strip was progressively lowered, transformation into alpha iron did not occur promptly; the gamma lattice persisted even at 1300° F. The optical pyrometer could not be relied on for lower temperature readings, so the exact transformation temperature could not be determined, but when the sample was cooled to room temperature, its structure was found to be alpha iron, as shown in the right-hand radiograph. When the same was reheated to 1300° F., the alpha iron lattice still persisted.

The transformation of gamma iron into alpha iron refines the grain size considerably. This is a very interesting event, because grain refinement did not occur in the low carbon steel when it transformed from gamma into alpha iron. These delayed transformations are in keeping with the general nature of high chromium steels.

The structural changes which were found to occur in cold rolled "Nevastain" (a high alloy steel containing about 16% chromium, 1% nickel and 1% copper) when heated to elevated temperatures were of unusual interest. These are shown in the group of three radiographs below. The left-hand view is the X-ray exposure of the cold rolled specimen. The grain fragments are oriented statistically with the (110) crystalline planes, tending to parallel the direction of rolling. The X-ray diffraction *(Continued on p. 176)*



At 70° F. | At 1640° F. | After Cooling

One Preferred Orientation in Complex 16% Chromium Steel ("Nevastain") Is Stable at Both Room and Elevated Temperature, While a Second Has Arisen From Changes Taking Place During Annealing

MINIMUM EQUIPMENT FOR METALLURGICAL CONTROL LABORATORY

THIS ARTICLE IS NOT FOR THE METALlurgist in a steel plant or non-ferrous mill, nor for his professional brother in a large, modern plant on mass production, but for the man in the small shop, fabricating better-than-average metal into parts or machines that are sold on quality rather than price.

To the management of such a plant there must come, sooner or later, the problem of getting the most possible out of available metal, of explaining the limitations of the material and fabrication processes to the designer, and of convincing the shop foreman that better ways to do it have been discovered since he was an apprentice. When that time comes a man already on the pay roll, or a new one added to the staff, is given these responsibilities, and for lack of a better name we will call that man a "metallurgist," no matter what his other duties are, or what his title (or lack of title) implies.

At this time the question of cost will arise. "What will be the cost of metallurgical control?" This article is an attempt to answer that question for the small plant taking its first steps in that direction — in other words, the problem of adequate metallurgical control with modest equipment.

It should immediately be apparent that the first essential is the metallurgist himself. No matter what equipment the plant has, or what it manufactures, no matter what the raw material, no matter whether the operations are performed by automatic machinery or hand work, in any plant "metallurgical control" is absent unless there is one intelligent man whose function it is to see that the material most adaptable for the manufacturing operation is procured, and to see to it that these subsequent manufacturing operations manipulate the metal without abuse so that at the end a quality product is built.

It should be emphasized that the largest expense and the most continuing expense of metallurgical control is the metallurgist himself. A reasonably workable laboratory can be installed once and for all and costs less than the total of the metallurgist's salary for the first year. That expense, once incurred, is all that is necessary beyond moderate amounts for upkeep and expansion, but the metallurgist's salary continues, month after month.

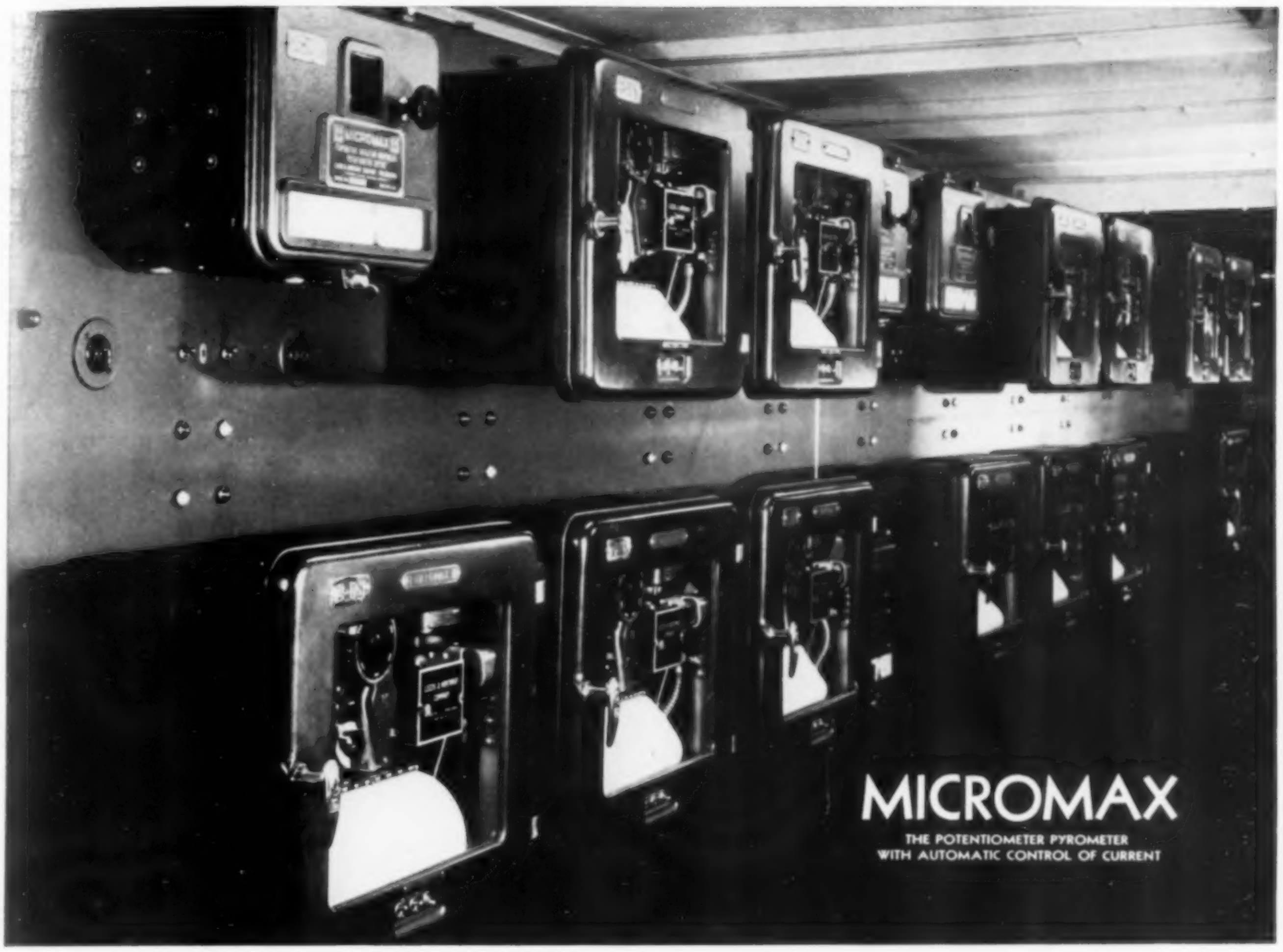
It is obvious, therefore, that unless the management is thoroughly convinced that money so spent is money well spent, it will be a mistake to install any equipment whatever for so-called metallurgical control. Only when it is used as a tool in an intelligent man's hands can the best furnaces, pyrometers, and testing equipment in the world do anything of value in improving the output or lowering its cost.

Let us assume now that the management has made up its mind that such a continuing expenditure for salary would be justified, and a man who will probably be able to do a satisfactory job is available. What are the minimum tools which he will need?

First I would say is a library — a record of inherited wisdom. By this I do not mean that he needs a whole wall covered with books. He must, however, have information (on almost every metallurgical matter under the sun) *(Continued on page 170)*

By Ernest E. Thum
Editor, Metal Progress

Portions of an Address Before Various Ohio Chapters, American Society for Metals



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MEASURING INSTRUMENTS AND CONTROL EQUIPMENTS

• See the Micromax Family and Triple-Control Hardening and Homo Dense-Load Tempering in L&N Booth at the Metal Show

I-394

(Cont. from p. 168) available some place close, so he can dig into it and find it when the necessity arises. It will be impossible to predict in advance what the question will be. One day it might be a matter of high speed steel, the next day free-cutting brass, the next day an undue run of breakages in the press shop, and the following day some hard spots on castings!

This library should be as encyclopedic as possible, and such a library has been accumulated for him during the last 20 years by our own Society. Any intelligent man who is able to use a complete file of publications of the American Society for Metals will find that it contains definite information on 75 out of 100 of the specific problems he must solve in daily work.

So let us put down as the first piece of equipment which should be bought for the new metallurgical department: One set of publications of the American Society for Metals at a cost of about $125.00. The metallurgist will then find that his success is limited only by his own ingenuity in applying the facts acquired from this storehouse.

Given the man and his library, he is ready for any one of a hundred things which might crop up on the spur of the moment in planning his laboratory and its equipment. However, he can arrange in advance only for the specific things which he would feel are really necessary.

Inspection for Uniform Material

One of the most important things which should be under metallurgical control is the receipt of proper and uniform material (with emphasis on the *uniform*). While it is impossible in the present state of knowledge to specify the characteristics which would make the metal best for forging, or for machining, or for pressing, the metallurgist should insure that the raw material coming in is as uniform as possible, bar-to-bar and shipment-to-shipment, so that production can be set up and planned to handle efficiently this particular kind of raw material, even though it might not be the best in the world.

Much stress is laid upon the chemical analysis of the raw material, yet it is not recommended that a chemical laboratory be installed in a small plant such as the one under discussion. There are enough qualified consulting chemists and laboratories available, and this work would ordinarily be better and more cheaply done by one of them. Reliable vendors of the metal can also give fairly accurate information concerning the chemical analysis of the shipment — ordinarily close enough for the purposes in view by the customer. Carbon content is probably the most important, and an estimate of plain carbon steels can be made by measuring its hardness in the normalized condition.

As a matter of fact, cleanliness and ill-defined qualities known as hardenability, machinability, "body," or "timber" are of greater importance in the selection of high grade steels than the chemical analysis. Cleanliness can best be judged by cutting a small cube from a representative sample in such a way that the longitudinal section half-way from the center of the sample can be polished. The unetched area of this metal surface can be examined under the microscope to get an idea of the number and size of the inclusions. This examination should be made in conjunction with the deep etch test; it is simple to cut a disk, smooth it roughly, and etch it in boiling acid, according to the recommended practice of the American Society for Metals. The interpretation of the deep etch test is a mater of skilled judgment, aside from major defects which would reject the metal definitely.

If the metal is to be carburized subsequently or if it is to be used in the quenched and hardened condition it is well to put a small sample of the metal through the regular hardening routine and examine the fractures, and the polished and etched surfaces. If the sample is to be carburized, the McQuaid-Ehn carburizing test is excellent to determine its suitability. If the material must be fine or coarse grained after a particular heat treatment (to insure toughness or machinability) it should be examined for grain size under a microscope after the specified heat treatment. If it is of tool steel grade it can best be appraised by the penetration of hardness and its susceptibility toward coarsening by the so-called P-F tests proposed by Shepherd.

From the above it will be apparent that the problem of inspecting incoming metal is one which requires a minimum of equipment but a maximum of intelligently keen eyesight! Some indications also appear as to the minimum of necessary equipment to be installed by the metallurgist. He has already turned thumbs down on chemical equipment, but he must, however, have equipment for heat treating and hardness testing and for microscopic examination up to 100×.

Before saying a few words as to the expense of this equipment, a few thoughts are appropriate about the need of making tests on the other physical properties of the metal.

Designing engineers have in the past and probably always will set great store upon those tests which determine (Continued on page 172)

(Continued from page 170) the ultimate tensile strength and ductility of the metal. Other engineers pay a good deal of lip service to the impact strength of metal, while still others are very insistent that fatigue tests are most important. However, for the general problem of a metallurgical department with a minimum of equipment, it may be assumed that these specialized problems will not arise. Of course, if they do special equipment must be installed.

For the purposes of general utility, metal should be high in tensile strength, tough under shock, and clean and sound internally. The best way to approximate the relative adaptability of a piece of metal, either as received or after alternative heat treatments, would be to test the material for these three properties, namely, strength, toughness and cleanliness. How can this be done with the minimum of equipment?

We have already indicated the manner in which internal cleanliness can be discovered. Lacking a tensile testing machine, a good idea of the strength can be had from the hardness. Equations and curves showing these relationships have been worked out for various metals and are available in the metallurgist's library. What could be simpler than to take a sample, heat treat it to standard condition, test it for hardness, and then take off the ultimate tensile strength from the curve or corresponding formula?

Sometimes nothing else but a tensile test will do. Then the best way is to send the work to a firm of inspecting or testing engineers. If such work is more frequent, one of the small hydraulic machines developed for testing samples in the field cut from welded pipe joints will be suitable. The cost is $700. If tension testing becomes a regular routine and one of the excellent hydraulic or lever type machines now available is installed, the metallurgical department will have outgrown the embryonic stages.

Testing for Toughness

As for "toughness" — one of the essentials of good metal — the metallurgist would do well to adopt the slow bend test described by A. B. Kinzel in *Transactions*, A.S.S.T., 1927. It should be emphasized that in making this test one is not simply interested in the angle of the bend, but in the elongation of the ultimate fiber at the outside of the bend.

The test is made on bars at least three times as wide as they are thick, and of any convenient length. The ends are both bent slightly over and then the bar squeezed endwise in a vise or press until the first signs of distress or fine fractures appear at the place where the bend is shortest. The amount of extension at the outer fiber may be read by a simple depth gage with a properly calibrated dial, costing about $15. Lacking this, a templet can be fitted to the curve, the radius of the arc determined by a pair of compasses, and the extension computed.

Of course, it is not to be inferred that impact testing equipment or the rotating beam fatigue machine would not be valuable adjuncts to most metallurgical laboratories, but since the subject of this article is metallurgical control with a *minimum* of expense, one must point out that considerable information can be secured concerning the important physical properties of metal in process by very simple means, namely, hardness testing, bend testing and deep etching.

Hardness Testers

Hardness testing machines are well enough known so that no description is necessary. The price of the Rockwell hardness tester ranges from $325 to $445, depending upon the size and design, and a good model for general use will cost $385. Undoubtedly the machine with spares and adjustable work supports can be secured and installed for a total of $400.

A Brinell machine for testing hardness can be bought for somewhat less money. Furthermore, a complete Shore scleroscope costs only about $275. It is not necessary to enter into a discussion as to whether the scleroscope or Rockwell machine or Brinell machine should be installed, but what should be emphasized is that one of the three machines is absolutely necessary before any metallurgical control can be exercised in a plant.

So far we have considered three essentials for metallurgical control; first, the man; second, his library; and third, his method of determining the physical properties of the metal in process. The reasonable assumption must now be made that the metallurgist will be continually on the look-out for any procedure to make the metal more amenable to his desires by appropriate heat treatments. This last phase of his activities requires two essentials — first, an accurate pyrometer, and second, a good furnace.

First class pyrometer equipments are so reasonably priced that there should be no excuse for installing anything but devices manufactured by reputable firms. Further, it should be obvious that metallurgical control means metallurgical control, and no control (Continued on page 174)

(Cont. from page 172) exists if the furnace temperatures are in any way doubtful. The metallurgist should have a calibrated thermocouple which is used for nothing except laboratory work and one with which he verifies the accuracy of similar equipment out in the shop.

As an indication of the reasonable price charged for high grade equipment, about \$100 will buy a high resistance indicating pyrometer of the millivoltmeter type, scale graduated up to 2400° F. and with automatic cold junction compensation. A base metal thermocouple and protecting tube cost less than \$20. With such equipment available for such a price, why worry along with anything less suitable? Recording pyrometers with the same range cost from \$235 to \$260.

It would be very well indeed if a rare metal thermocouple could be used for a permanent standard in the laboratory and this also costs surprisingly little, approximately \$60 for a platinum thermocouple 12 in. long. For a slight additional cost the indicator dial can be printed with a double scale to read directly for both base metal and platinum thermocouples.

It may, therefore, be stated that for approximately \$325 a recording pyrometer with both base metal and rare metal thermocouples, complete with protecting tubes and lead wires, can be secured.

Laboratory Furnaces

As to the laboratory furnace, either a gas furnace or an electrically heated one will serve very well. A muffle type electric furnace with heat treating chamber about 8 in. wide, 5 in. high, and 12 in. long will serve for a large number of investigations. The price, including switchboard and transformer, suitable for 60-cycle current, 110 volts, is about \$325. Temperature is controlled by a regulating transformer whose cost is included in the above figure. If automatic control in such a furnace is desirable, it can be had for \$225. It will be apparent, therefore, that for an expenditure of \$325 to \$550 a very adequate electric furnace equipment can be installed.

If a gas furnace is desired, an excellently made hearth furnace, slightly larger, will cost \$250, complete with burners and valves for hand adjustment. Automatic valves for control will add \$90 to this figure (if the necessary pyrometric equipment is available).

As inferred at the outset, a small microscope will be very useful, first for examining the cleanliness of steel, next its grain size, and last its response to various heat treatments. About the cheapest instrument manufactured by responsible concerns is a shop microscope suitable for magnifications of 40 diameters. This costs \$45 and would be suitable for the visual examination only.

This figure should be increased to \$75 to include the cost of polishing papers and abrasives (polishing to be done by hand) and a supply of etching reagents and glassware.

Photomicrographic Equipment

The metallurgist will speedily find that photomicrographs are necessary when he discusses problems with other members of his organization, and even in corresponding with suppliers of his material. This will require a rather better and more rigid microscope, costing about \$100 with one set of lenses, an illuminator (\$20) and a camera bellows and stand to place over the eyepiece (\$100). (Metallurgical microscopes, illuminators and cameras mounted on a single bench will cost from \$500 up, depending on the lens equipment and number of accessories desired.) There will also be the expense of developing and printing equipment which may run up to about \$50, if a suitable dark closet is available.

In conclusion, we may list the items. Aside from salary cost, the absolute minimum may be:

Library	\$ 75.00
Hardness tester	275.00
Pyrometer	120.00
Gas furnace	250.00
Shop microscope and accessories	75.00
Bend extensometer	15.00
Miscellaneous furniture and installation	100.00
Total	\$910.00

It would appear that the cost would be about \$1000 at the start, and well worth it to any concern which really desires meallurgical control. Such an organization would be well advised to "plunge" to the extent of \$3000; thus:

Library	\$125.00
Hardness tester	400.00
Pyrometer	325.00
Automatic electric furnace	550.00
Tensile and bend testing equipment	715.00
Microscope and camera	250.00
Dark room equipment	50.00
Furniture and installation	250.00
Total	\$2665.00

X-RAY EQUIPMENT

(Continued from p. 166) pattern at 1640° F. is shown in the center; a new recrystallization orientation has appeared. On cooling to room temperature, a second orientation appears along with the one present at the elevated temperature, as shown in the right-hand print. In other words, two orientations are present instead of only one.

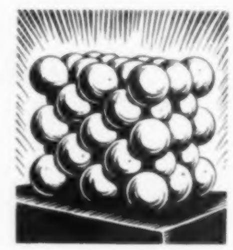
It is at once apparent that if only the X-ray patterns at room temperature, both before and after annealing, had been considered, an erroneous conclusion would have been reached, namely, that only one recrystallization orientation was developed by heat treating. As a matter of fact, one of these is stable at both room and elevated temperature, while the other transforms as the temperature is lowered. (The transformation temperature was not determined.) This is a very important result, and bears a fundamental relationship to the physical characteristics.

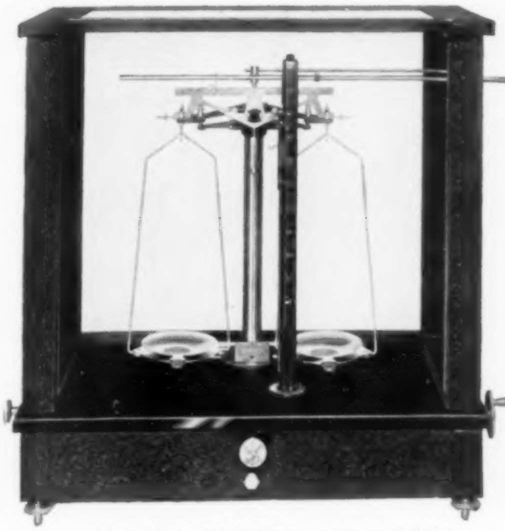
Advantages of New Equipment

In summary, it may be pointed out that this new cassette permits us to make X-ray diffraction patterns at elevated temperatures with ease and rapidity. Since the film is mounted on the outside of the cassette, the specimen need not be disturbed during the entire investigation. The bakelite cylinder about which the film is mounted easily transmits the characteristic radiation of molybdenum but absorbs the scattered and stray radiation which would otherwise fog the film.

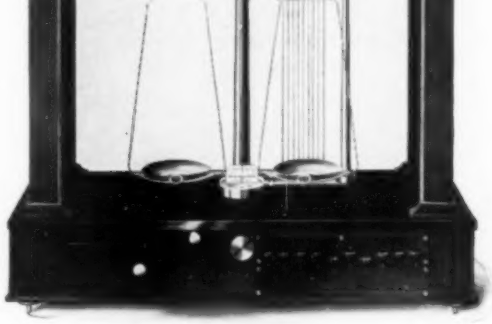
A progressive series of X-ray diffraction patterns can be made of any specimen, over a large temperature range either on heating or cooling, thus permitting one to follow structural changes occurring within the specimen.

The stability of the grain structure can also be studied at any given temperatures, since the heat can be held indefinitely and the X-ray film replaced at regular intervals without disturbing the specimen. The effect of various gases on the grain structure can also be easily studied.

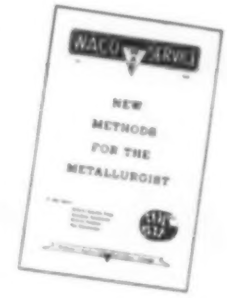




New Chainweight Balance, Type DLB



Keyboard Balance—Type TC



y Cleveland Tractor Co.

FORGING
AND
PRESSING

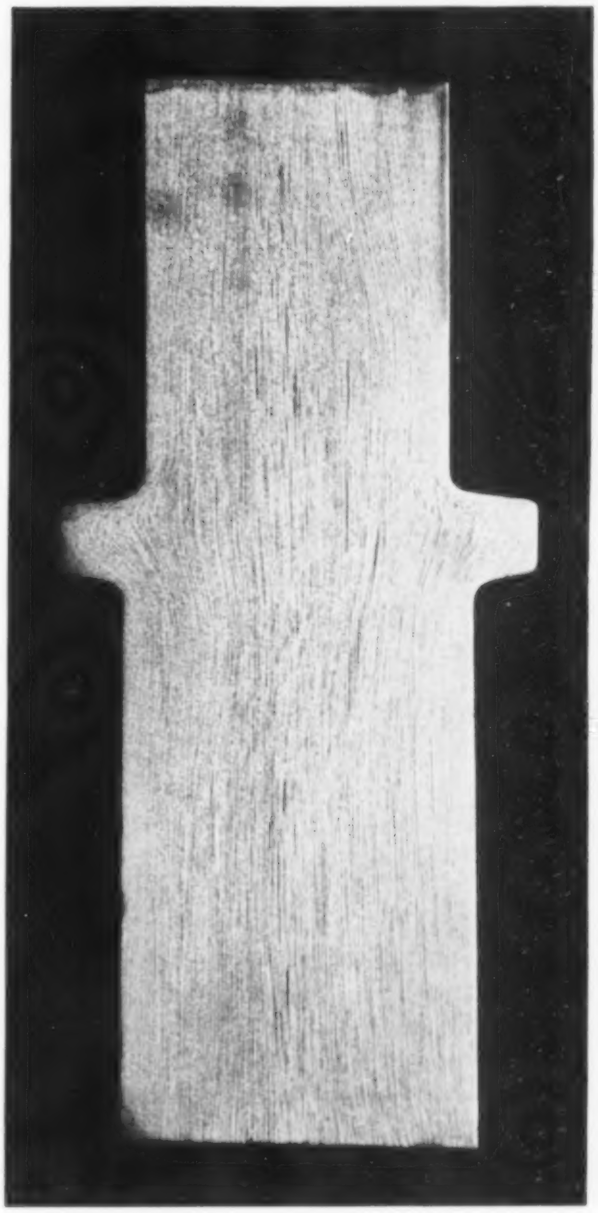
Demand for Forgings of Close Dimensions and Weight Tolerance Has Resulted in More Precise, Rugged Forging Machinery and Unusual Precautions in the Shop . . . Product Must Meet Exacting Specifications, Unheard of a Few Years Ago

GRAIN CONTROL IN PRECISION DROP FORGINGS

LOOKING BACK TEN YEARS OVER THE HISTORY of the steel forging industry, one notes a number of important swings, some due to fundamental changes in other industries, some due to competition by castings and stampings, some due to improved metallurgy of steel, and others due to the business depression of the early 1930's. Frequently the causes are mixed, and the effects not recognized quickly — all of which goes to show that the management has had a difficult time in adapting plant and organization to needs of the day. In fact, problems of finance and organization have doubtless been more difficult to solve than the metallurgical ones.

Comparing conditions as they exist today in the independent forge shop with those of ten years ago, the most striking thing is the diversity of work going through — the number of small jobs with special requirements and the comparative rarity of an order large enough and repeated often enough to warrant relocating a battery of machines and furnaces to handle heavy production in an economical and expeditious manner. It is unfortunately true that during the middle and late twenties many of the large users of forgings — such as automobile manufacturers — during a period of rapidly advancing sales of automobiles, added forging departments to their plants. At the same time, plants such as ours added materially to their equipment, and the industry finds itself over-expanded during the last few years of lower car sales, while at the same time the car manufacturer finds himself with a forge department investment of his own. In 1934 the Transue & Williams Steel Forging Corp. — only one unit in the industry

By R. W. Thompson
Chief Metallurgist
Transue & Williams Steel Forging Corp., Alliance, Ohio



Controlling Grain Flow (as in This Wrist Pin) Is the Art of Forging a Billet so That the Fiber in the Original Bar Is Left Intact and Unsheared

— had almost as large capacity as the actual combined production of all the independent forging plants for that year.

This situation in the forging industry has brought about the installation of improved modern equipment of the very latest type possible to obtain, resulting in a condition where it is possible to obtain prices from the forging specialist which are below the cost of the same products made in their own departmental shops.

Extreme diversity of production is therefore the rule at present. Jobs are taken on that would not be considered worth bothering with in the old days, hoping that they will lead to close cooperation with newly developing enterprises. We are inclined to suspect at times, too, that some of the larger industries let us work out their more difficult forgings! At any rate, it has brought the drop forger into contact with new problems of economical production of relatively small lots to meet difficult specifications. It has caused us to install fuel control systems, heat treatment departments, cleaning and finishing equipment, and a metallurgical control and inspection which would cause an old-timer to wonder what the world is coming to.

Typical jobs made to these special requirements may be roughly grouped as those involving special alloys, those where grain size must be controlled, those made to close dimensions, and those that must be heat treated to close specification.

Regarding the first item — special alloys: Alloy steels are of course no novelty. However, stainless steel and forgeable brasses are rather unusual items for the average forge shop. An interesting article could be devoted to this alone, but the present author has published an article on forging the stainless steels in METAL PROGRESS for April, 1933.

Heat Control for Gear Blanks

An outstanding example of the second type above mentioned is an 88-lb. forging for the main ring gear for rear axle transmission on heavy trucks. Steel required is the so-called Krupp analysis (S.A.E. 3312 modified by higher nickel, 3.75 to 4.25%), purchased from the most experienced American manufacturer of this analysis of steel. It has controlled fine grain, according to the McQuaid-Ehn test. The forgings must be delivered with proper flow of fiber, with fine grain uncoarsened by the forging heat, machinable and free from internal stress or non-homogeneities which would cause undue warping in the very extensive subsequent heat treatment and

Large Ring Gear Forging Being Finished on 10,000-Lb. Hammer. Correct grain flow, freedom from internal stress, and homogeneous physical condition are essential in such a gear blank

machining. It is our problem, in other words, to turn over a superfine forging to the gear cutter. There our responsibility ends, although we are often impressed with the fact that it is all too easy to spoil a good forging by improper carburizing or hardening, yet it is impossible to correct bad forge practice by subsequent heat treatment, and it is all too difficult to convince some purchasers that care in the forge shop is worth a little extra money.

First requirement of a stress-free forging is slow and thorough heating prior to hammer work. The 6-in. round slugs (sawed, not sheared) weighing nearly 100 lb., are preheated in a furnace at 1650° F., staying here a total of 2 hr. 45 min. They are then transferred quickly to the high heat furnace (2250° F.) remaining there on the average 1 hr. 15 min., and are withdrawn for forging at a uniform heat of 2225° F., edge to center. This, it will be recognized, is rather hot, yet it is necessary to forge this analysis near the upper limit because it is

High heats such as this involve three important considerations, namely temperature control, scale production, and grain growth. The first two will be discussed later. The third can be dismissed by saying that the steel as bought is an inherently fine grained steel which does not coarsen until a very high heat is reached, and what coarsening does occur is corrected by the hammer working.

First operations on the round slug are between dies with domed faces, which gather the metal in a heavy rim around a fairly thin center disk. The very center is punched out, and the ring returned to a third furnace. Here the hot pieces are soaked at 2100° F. for 30 min. to equalize temperature edge to center, and finished in a die by a few blows on a 10,000-lb. steam hammer, and trimmed hot. This work is done quickly, and a milder temperature is necessary so the work may end near the lower limit of the forgeable range. Each piece as finished is cooled individually and out of drafts by spotting it

very tough, even when hot, and the central region of the mass does not move unless hot enough to be plastic, and hit hard enough by a big hammer. An 8000-lb. steam hammer is necessary so that the work can be done without too many blows, thus avoiding surface cooling by contact with forging dies. Added time on a lighter hammer would mean more cooling by radiation, and the gross result would approximate "cold working" of the metal, slightly below its narrow forgeable range. This condition would quickly show itself by cracks where roll marks, tiny seams or other slight imperfections occur in the original stock, and by development of wrinkles and incipient laps on the stiff surface.

carefully on the corrugated bottom of a tote box to insure an equal and uniform cooling on all surfaces. (Lime cooling is necessary in winter to prevent too rapid a temperature change).

It is obvious that this job involves a number of essentials which can only be provided by careful organization — correct heating, working under large hammers in dies which control the flow of fiber, reheating to avoid cold work, and controlled cooling. All these items are far removed from the free and easy practices of the drop forge industry in what might be called the "railroad spike era."

Outstanding examples of forging to close dimensions are seen in current specifications for

connecting rods for automobile engines. Demand for quiet, well-balanced running, and desire to minimize expensive machine work have resulted in demands that the forge shop shall produce forgings within a weight tolerance of plus or minus 1 oz. This holds for about 30 varieties produced by Transue & Williams, weighing from 2 to 4 lb. Further requirements are met by coin pressing the faces of the two ends, so that the thickness is within $\pm$ 0.005 in. of dimension and one boss is parallel to the other within the limits zero to 0.005 in. Many such rods are merely broached for bearings and perhaps rifle-bored for oil supply, and are then ready to be matched by weight with others and assembled in the engine.

Forging Connecting Rods

The usual steel for connecting rods is S.A.E. 1045, purchased as a controlled fine grained steel. From a forgeman's standpoint, its principal advantage is that such steel seldom or never cracks when flash is sheared off. His troubles begin when forgings of such size must be held to such close limits of weight. This means that dies must be accurately cut and placed in excellent hammers which can hold this accuracy. Furthermore, the die must be reworked before it wears out (in the old sense of the word) whenever the wear increases the dimensions of the finished forgings beyond a very small limit.

Stock must, of course, be accurate, but scale and decarburization must also be under control. The latter is of more importance to the purchaser. Of course, scale represents lost metal, and if too much is present pieces of it may get caught in the dies and make marks on the forging that cannot be eliminated in later work. But the purchaser is now beginning to worry about decarburized skin in highly stressed forgings. Obviously if 0.45% carbon steel is needed to carry the loads, trouble may arise in service if too much of this metal at the surface is a weaker steel containing half or less carbon content.

Hot rolled bars from the steel mill have a skin from 0.012 to 0.015 in. thick which has notably lower carbon than the bulk of the bar. This arises from the same conditions existing in the soaking pits and billet heating furnaces that are found in the forge furnaces — namely an atmosphere that scales the steel and decarburizes the underlying metal. Therefore, even when an oil or gas flame is operated slightly on the "reducing" side, the heating and forging operation will scale off from 0.010 to 0.015 in., but at the same time a slightly decarburized surface persists.

This situation is intensified in the longer heats required for billets for large work, but is present even when heating small bars. We have experimented with atmospheric control to a considerable extent at Transue & Williams plant, and while some progress can be recorded, it is significant to note that further investigations will undoubtedly bring us to improved conditions in the future.

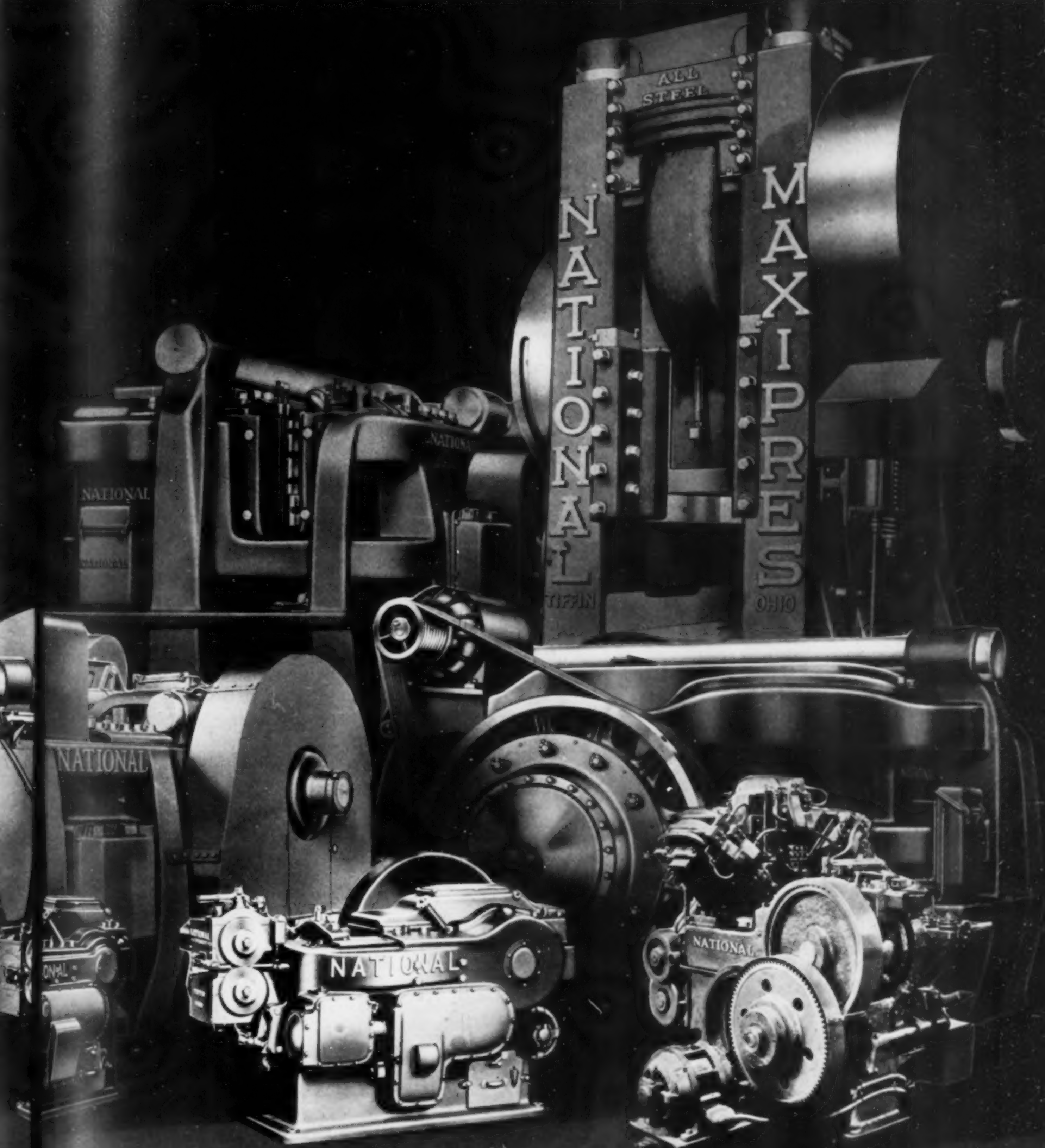
Some notes on our present situation will be interesting: In the first place all forge fires are centrally controlled — that is to say, the forgeman has nothing to do with flame adjustments. This step is seen to be necessary when the varied production as to alloy, size, die design and acceptance requirements is remembered. Temperatures are automatically controlled from a central pyrometer room; valve adjustments for fuel and air are also made by the heat supervisor. Definite schedules are set up by the metallurgical department for each forging, and must be followed.

In the second place, the large fires are heated by diffusion combustion, where a series of alternate layers or blankets of gas and air fill the furnace. The advantages of this method of combustion have been discussed in several recent articles, and need not be repeated. It is our aim, of course, to have a relatively thick layer of raw gas hugging the hearth, to protect the hot metal from reaction with oxygen. This it does, in fact, as long as doors or slots are closed and conditions inside are undisturbed by putting in cold work and withdrawing hot. Otherwise, sufficient disturbances are created to cause turbulent flow and loss of much of the theoretical advantage of this type of protection. At its worst, however, we are satisfied that a diffusion gas flame is a distinct step forward, and enables us to heat billets without producing more scale than on the original bar, and with the least decarburization.

In other words, we are approaching a neutral atmosphere in our heating furnaces. The hot billet scales rather freely as soon as it is removed from the furnace and during forging; at this time decarburization is less active, and the result is a finished forging wherein the surface has a better approximation of the correct analysis than anything achieved by the old and uncontrolled methods of heating.

A similar control of heating atmospheres must extend through subsequent hardening operations, for connecting *(Continued on page 194)*

N PERIOD ENGINEERING!



MACHINERY CO.
OHIO

Chicago

DROP FORGINGS

(Continued from page 190) rods are ordinarily quenched and drawn to definite hardness. In other words, a neutral to slightly oxidizing atmosphere is necessary in the furnace to control decarburization and produce a soft scale that will loosen completely in quenching, and thus prepare a uniformly hardened forging. Connecting rods are ordinarily restruck on the draw heat — in reality a hot straightening operation — and then coined when cold.

Special Heat Treatments

This matter of special heat treatment is pushed to its extreme when purchasers specify not only the required hardness but "suggest" desired heat treating program and quenching medium. Of course, the luckless drop forger can disregard these suggestions if he wishes, but then he would have small defense against an overzealous inspector!

A case in point is an automobile forging now in production, made of S.A.E. X1035 (manganese on the high side, 0.70 to 0.90%). This forging is Brinelled 100% and must be within the range 269 to 321, which is not difficult to meet by a simple quench from 1500° F. and a draw at 950. However, a cup has been pressed into one end, 7/8 in. deep and 1/8 in. wall, and quenching cracks will develop at the bottom of the walls inside or longitudinal cracks near the top. Owing to the carbon and manganese content, these thin walls harden to the center, and a water quench is too drastic. Hence it is necessary to quench these forgings in a 4% caustic solution, adjust the conveyor speed so they are taken out of the bath while still quite hot (400 to 600° F.) and placed immediately in the drawing furnace. It is my opinion, also, that the higher uniformity in Brinell tests on forgings quenched in caustic solution over those quenched in water is due to the fact that caustic loosens the scale much more quickly and thoroughly, thus removing any blanketing effect and allowing the liquid to reach immediately the clean, hot metal.

* * *

Perhaps this forging story has turned out to be more or less of a heat treating story. If so it is merely another proof that the drop forger today has to be equipped to do the impossible (as viewed in 1925) if he is to remain in business.

MANUFACTURERS' BULLETINS CONTAIN VALUABLE DATA SENT FREE ON REQUEST

Cast Iron Metallurgy

One of International Nickel Co.'s data sheets tells all about the metallurgy of nickel cast iron in a not-too-technical manner. Special applications to petroleum production equipment are stressed. Bulletin Ox-45.

Electrotinning

E. I. du Pont de Nemours & Co.'s new manual on the sodium stannate-acetate electrotinning process is particularly timely. Electrodeposition, at first considered useful only for tin coating of recessed and irregularly shaped objects, by reason of recent improved and economical methods is now being considered favorably for all types of work. Bulletin Ox-29.

Mo-W High Speed Steel

In a four-page folder, The Cleveland Twist Drill Co. announces the development of a new steel for high speed metal-cutting tools. Mo-Max steels are particularly suited to tools subjected to severe conditions of heat and abrasion. Physical characteristics and heat treating temperatures are discussed. Bulletin Ox-103.

Grain Size Measure

Classification of steels by grain size has become such an important laboratory procedure that Bausch & Lomb Optical Co., at the suggestion of Dr. Marcus A. Grossmann, has developed a grain size measuring eyepiece for microscopes which makes the determination a simple, routine matter. Described in Bulletin Ox-35.

Machine Steels

Because of the rapidly increasing use of rolled steel in machine construction, Illinois Steel Co., in collaboration with Carnegie Steel Co., has prepared a handsome technical booklet on this subject. It is one of the most complete works ever offered to cover this new field. Bulletin Ox-1.

Refractory Mortars

How a good refractory mortar, properly fulfilling its functions of air-seal, cushion, and bond, will pay for itself in the extended service of furnace brickwork is told in Babcock & Wilcox's bulletin giving properties and recommendations for using various mortars and plastics. Bulletin Ox-75.

Electromet Review

A very attractive new house organ has recently made its appearance. It gives news and views of alloy steels and irons, but is mostly concerned with stainless steels. Electro Metallurgical Co. publishes it. Bulletin Ox-16.

Nickel-Copper Steels

Exceptional resistance to corrosion and abrasion, increased tensile strength, and higher ductility are the qualities claimed for Youngstown Sheet & Tube Co.'s new series of Yoloy steels. A summary of properties and notes on their characteristics are contained in Bulletin Ox-93.

Vanadium Facts

Revived after nearly 20 years is the house organ of Vanadium Corp. of America, "Vanadium Facts." This paper shows considerable thought and care in its preparation and contains valuable and interesting information on vanadium steels. Bulletin Ox-27.

Machining Handbook

This little handbook giving machining properties and a great deal of other related data for a wide variety of steels should be of much value in aiding the steel user to select the right steel for the right purpose. Union Drawn Steel Co. Bulletin Ox-83.

Tool Steel Selector

A wall chart, 30x20 in., to be used as a means for selecting the proper type of tool steel, is offered by Carpenter Steel Co. to tool steel users in the U.S.A. only. Bulletin Jzx-12.

Die Steel

Darwin & Milner has two folders on their "Neor" non-deforming high carbon chromium steel and "Patent Cobaltchrome" steel for dies. Properties, applications, and detailed instructions for treatment are given. Bulletin Ox-91.

Double Strength Steel

A large fund of authentic information on Republic Steel Corp.'s new double strength steel is contained in an article by Howard L. Miller reprinted from Metal Progress. This steel promises wide application where a high tensile steel is required. Bulletin Ox-8.

Amsco Alloy

Amsco Alloy is the heat and corrosion resistant alloy made by American Manganese Steel Co. Its many uses, including application suggestions on each different analysis, are given in Bulletin Ox-9.

Tool Room Furnace

A new type of lining and one-valve control are two of the features of the American Gas Furnace Co.'s new tool room oven furnace that would make it economical to replace many older furnaces now in operation. Fully described in Bulletin Ox-11.

Optical Pyrometer

A simplified optical pyrometer which is compact, easy to operate, light, and entirely self-contained is invaluable in iron and steel manufacturing plants, heat treating, forging, rolling, and wire drawing plants. Such an instrument is marketed by Pyrometer Instrument Co. and is fully described in Bulletin Ox-37.

Industrial Thermometers

A striking new Industrial Thermometer Catalog has just been issued by C. J. Tagliabue Mfg. Co. It contains 24 pages of conveniently arranged listings of industrial thermometers, miscellaneous metal and woodback thermometers, hygrometers, U gages, mercurial vacuum gages and mercurial barometers. Bulletin Ox-62.

Phosphor Bronze

An interesting little history of bronze from antiquity to the present prefaces a complete description of the properties, composition, uses, and shapes available of Seymour phosphor bronze in a folder by Seymour Mfg. Co. Bulletin Jyx-48.

Burners and Valves

Auxiliary equipment for industrial furnaces that will insure proper heat production and correct combustion, such as oil and gas burners, blowers, regulating and shut-off valves, is fully described in Mahr Mfg. Co.'s illustrated booklet. Bulletin Jyx-5.

Compounds, Lubricants

J. W. Kelley Co.'s line of Beacon Brand products — industrial oils, carburizing compounds, heat treating salts, greases, and cleaners—is described in a little booklet which also tells about the company's experience, equipment, and facilities for quick service. Bulletin Ox-102.

Sheffield Steels

Wm. Jessop & Sons, Inc., have a leaflet which tells why a special anneal and a proper balancing of carbon, manganese and tungsten combine to make Sheffield Superior oil hardening steel non-distorting and easily machinable. Bulletin Jn-61.

Casting Problems

Unusual casting problems that were solved by the use of National Alloy Steel Co.'s oxidation, corrosion, and abrasion resisting castings are shown in a clever pictorial manner in an attractive folder. Bulletin Ox-104.

DX Units

Surface Combustion Corp.'s DX unit is a machine for producing an inexpensive gas for controlled atmospheres in industrial heating processes. Its operation and applications are covered in Bulletin Ox-51.

New Homo Furnace

The new Homo furnace described in a bulletin issued by Leeds & Northrup provides for even tempering on a very dense load. Automatic control includes a feature that prevents overshooting. Fine tempering on extra dense loads at low cost is provided. Bulletin Mx-46.

Aluminum Castings

A new edition of the British Aluminium Co.'s booklet on "Aluminum Alloy Castings" contains the latest casting specifications of the Society of Automotive Engineers and the American Society for Testing Materials in condensed form. Bulletin Ox-101.

Annealing Coiled Strip

How G-E bell-type furnaces for bright annealing coiled steel strip produce a uniform, high quality product is told by General Electric Co. in Bulletin Jyx-60.

Useful Wall Chart

Wyckoff Drawn Steel Co. offers a big new wall chart full of such useful data as comparative machinability of S.A.E. steels, tables for selecting steels according to machinability, cold forming properties, carburizing and hardening ability. Bulletin Ox-99.

Heat Treating Bath

A new folder on A. F. Holden Co.'s Light Case, which is showing savings of 10 to 20% for depths of case up to 0.010 maximum as compared to sodium cyanide, is available. Bulletin Ax-55.

√ ### Polishing Machine

A reprint of an article from the A.S.M. *Transactions* by O. E. Romig and J. C. Whetzel is supplemented by photographs, specifications, and other information on the Cincinnati Electrical Tool Co.'s new metallographic polishing machine. Bulletin Ox-97.

The Prevention of Rust

"Proof of Results" is the apt title of a new booklet issued by Dearborn Chemical Co. Dozens of photographs, supported by an interesting text, show how No-Ox-Id keeps steel from rusting. Bulletin Mr-36.

Brass and Copper Shapes

A general classification of the diversified products made by the American Brass Co. comprises copper and copper alloyed with zinc, tin, nickel, lead, silicon and manganese in all combinations that can be wrought into sheets, wire, rods, tubes and special shapes. Bulletin Ox-89.

Rotoblast

A new blast cleaning machine eliminates the need for compressed air as the abrasive driving agent. Pangborn Corporation tells how a rapidly spinning wheel propels the abrasive by controlled centrifugal force. Bulletin Ox-68.

Resistor Furnaces

Hevi Duty Electric Co. announces the first of a line of industrial furnaces using metallic resistor elements, permitting operating temperatures to 2300° F. in either oxidizing or reducing atmospheres. Bulletin Ax-44.

Long Time Creep Tests

Calorizing Co. offers a report presenting long time high temperature creep values on chromium-nickel alloys. This bulletin contains many pertinent data and recommendations as to safe working stresses for heat enduring castings at temperatures from 1400 to 2000° F. Bulletin Mr-26.

Fast-Cutting Steel

Bliss & Laughlin, Inc., offer an interesting technical folder on Ultra-Cut Steel, giving performance records of this high-speed screw stock on automatic screw machines. Physical data and microstructures are presented. Bulletin Ob-42.

Heat Resisting Alloy

Ohio Steel Foundry Co. offers an elaborate booklet covering the production of Fahrite heat resisting alloy castings, illustrating their many uses and giving comprehensive metallurgical data. Bulletin Ob-40.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Stainless Steel Uses

The wide range of applications of Allegheny Metal, best known of Allegheny Steel Co.'s corrosion and heat resistant steels, is pictorially covered in a new and interesting booklet. Bulletin Ob-92.

√ ### Pyrometer Supplies

Claud S. Gordon Co. offers a large catalog giving prices and descriptions of the great variety of pyrometers and pyrometer accessories carried in stock for quick delivery. Bulletin Ob-53.

Refractory Cements

The control of heat in many industrial processes depends upon refractory materials that may be sprayed, painted, poured, trowelled, or rammed into position. Norton cements for these purposes are described in a booklet which has an appendix giving tables and miscellaneous information of great value to furnace operators. Bulletin Ox-88-A.

Forging Machines

National Machinery Co. has published a large and very attractive booklet which by excellent illustrations and well written text tells how forging machines are built and why they produce accurate forgings. Bulletin Ob-14.

New Way to Case Harden

Chapmanizing, the new method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given out on the method itself and on its metallurgical advantages. Bulletin Ob-80.

Titanium in Steel

The use of ferro-carbon-titanium in steel is thoroughly described in a booklet of Titanium Alloy Mfg. Co. Titanium's application in forgings, castings, rails, sheets and plates is interestingly explained. Bulletin M-90.

Belt Preservatives

Houghton has something to say about belt preservatives in a folder containing information on when, how, and why to use preservatives or dressing. Various types are described. Bulletin Ayx-38.

Pre-Heating Furnace

General heat treating operations up to 1900° F., pre-heating of high speed steel, annealing and firing of glass are some of the applications listed in American Electric Furnace Co.'s folder on their new model B-20 furnace. Bulletin Jx-2.

Air-Clutch Forging

Two bulletins are offered by Ajax Mfg. Co. One tells about their air-clutch forging machines in 2 to 7-in. sizes, made according to the most advanced design. The second is concerned with the Ajax-Hogue wire drawer, an attachment for heading machines which presents new economies. Bulletin Ox-105.

√ ### Furnace Insulation

Johns-Manville offers to those who design or operate furnaces a new 72-page book describing insulation methods which improve performance and reduce operating costs. Requirements for each particular type of heating equipment are analyzed and detailed recommendations made accordingly. Bulletin Ox-100.

(Additional bulletins and order coupon on next page)

MANUFACTURERS' BULLETINS

SENT FREE ON REQUEST

Metameter

Information on Bristol Co.'s Metameter, which makes it possible to control temperatures, pressures, levels, and other process conditions or operations at any distant place, is contained in Bulletin Ax-87.

Spoilage Insurance

C. I. Hayes, Inc. has compiled a record of reports from over 300 users of their "Certain Curtain" controlled atmosphere furnaces showing how these furnaces have cut down spoilage in the heat treatment of tools and parts. Bulletin Sx-15.

Structural Welding

Reprints of an interesting article in *Journal* of the American Welding Society by A. F. Davis, covering welding of penstocks, a bubble tower, siphons, pipe lines, and an ocean pier, have been prepared by Lincoln Electric Co. Bulletin Sx-10.

Centrifugal Compressors

B. F. Sturtevant Co. has a line of centrifugal compressors designed particularly for industrial furnace applications. These are illustrated and described in Bulletin Myx-58.

Radium Radiography

Advantages of portability, ease of application and manipulation in examination of castings, forgings, molds, weldings, and assemblies are attributed to radium for industrial radiography. Details are given in a booklet issued by Radon Co., Bulletin Jx-56.

Steel Specifications

A handy, up-to-date specification sheet for carbon and alloy steels is offered by Timken Steel & Tube Co. On one page are printed analyses of all important types of Timken steels. Bulletin Jy-71.

Pyrometer Accuracy

A thought-provoking folder of Hoskins Mfg. Company explains how the use of Chromel-Alumel for pyrometer lead-wires makes it possible to take full advantage of modern pyrometric instruments. Bulletin Ob-24.

Pyrometer Drive Unit

For installations where their potentiometer control pyrometers are to be used singly, the Foxboro Co. has developed an improved type of motor drive unit. A new bulletin describes this unit and gives complete details regarding Foxboro potentiometer controllers. Bulletin Ox-21.

Air-Operated Controllers

The simplicity and outstanding performance of Brown Instrument Co.'s new Air-o-Line air-operated controllers, with their interchangeable control units and "ready-at-hand" adjustments, make them a revolutionary contribution to a large range of diversified industries. Bulletin Ox-3.

Silico-Manganese Steel

Silico-Manganese steel for heavy duty springs is the subject of Bethlehem Steel Co.'s new folder giving its properties and recommendations for heat treatment. Bulletin Jyx-76.

Balances

A chainweight balance and a keyboard balance are two new pieces of laboratory equipment whose speed and accuracy meet the most exacting demands of the user. Wm. Ainsworth & Sons, Inc., describes their complete line of balances and weights in Bulletin Ox-109.

X-Rays for Foundry

Not only foundrymen, but all those interested in X-ray inspection for internal defects should be interested in this booklet, which is in reality an interesting article on the subject, illustrated by excellent radiographs. Kelly-Koett Mfg. Co. Bulletin Ox-107.

Tool Steels

Three little folders concisely describe three types of SKF tool steels, give their uses and recommendations for heat treatment. They are a carbon tool steel, an oil hardening steel, and a high alloy general purpose tool steel. Bulletin Ox-78.

Cutting and Grinding

Sun Oil Company has prepared a folder showing cutting and grinding operations with facts on use of oils in these operations. Bulletin Ob-52.

Seamless Tubing

A most interesting circular detailing the manufacture and production of cold drawn seamless tubing in a complete but non-technical manner is obtainable from Summerill Tubing Co. Bulletin Ox-108.

Blast Gates

A blast gate that combines the full pipe area of a heavy gate valve with the quick action of a stop-cock and costs less than either is described and illustrated in a folder by W. S. Rockwell Co., manufacturers of industrial furnace equipment. Bulletin Ox-34.

Forging Service

An illustrated folder shows a number of unusual equipments used in the shops of the Kropp Forge Co., including the acetylene torch pantograph, bar straightening equipments, etc. Bulletin Ox-77.

Metallographic Methods

"WACO Service" suggests application of the newer methods to daily routine. Included are the new bakelite specimen mount, low cost polishers and grinders, and an offer of sample Selvyt polishing cloth. Wilkens-Anderson Co. Bulletin Ox-7.

Stock List

It takes six pages just to index the products described in Joseph T. Ryerson & Son's Stock List. Products vary from channels and angles to such things as stair treads, and materials are carbon, alloy and stainless steels, brass and copper, babbitt, and other non-ferrous metals. Bulletin Ox-106.

Laboratory Furnaces

Tiny induction furnaces which will melt ½ lb. of steel in 8 min. or 4 lb. of copper in 35 min. find a wide variety of uses in many kinds of laboratories. Ajax Electrothermic Corp. tells all about these small laboratory furnaces and the 3-kw. converter used with them in Bulletin Ox-41.

Steel Data Sheets

Wheelock, Lovejoy & Co. gives analyses, physical properties, heat treating instructions, and applications of Hy-Ten, Economo, and S.A.E. alloy steels in concise and easily usable form. Bulletin Ox-74.

Gear Steels

Those who have gear problems of any type can get valuable assistance from Endicott Forging & Mfg. Co., specialists in the manufacture of gear blanks. They carry in stock a large assortment of standard gear analyses and will manufacture to customer's blueprints and specifications. Bulletin Ox-65.

Forging Machines

The Acme Machinery Co. has just published an interesting bulletin on a distinctly new forging machine—the Model 35 Acme. This booklet illustrates and fully describes the new Acme Eccentric Header Slide which eliminates entirely the conventional Pitman construction. Bulletin Ox-39.

Swedish Tool Steels

"Pure-Ore" is a high carbon, high chromium Swedish steel especially valuable for dies in high production work. It is described in a folder by Kloster Steel Co., which is accompanied by a second folder describing "Swed-Oil," a non-shrinking, oil hardening tool steel which assures safety in hardening. Bulletin Ox-72.

Misco Alloys

Compositions, properties, and application of Misco stainless, heat, and corrosion resisting castings are given in an illustrated folder offered by a pioneer producer, Michigan Steel Castings Co. Bulletin Mx-84.

Rockwell Tester

The Rockwell Superficial Hardness Tester is applicable to far thinner sheet and strip than the regular Rockwell. Its use for nitrided and case hardened parts is also described by Wilson Mechanical Instrument Co. in Bulletin Myx-22.

Controlled Steels

Carnegie Steel Co. has published a very interesting booklet which describes in some detail the process control used in the production of uniform steels. Bulletin Je-85.

Welding Metallurgy

J. H. Critchett, vice-president of Union Carbide & Carbon Co., has prepared an exceptionally informative discussion of the physical and chemical principles involved in the oxy-acetylene welding of steel. Bulletin Ayx-63.

Conveyor Furnaces

Continuous chain belt conveyor furnaces handle miscellaneous parts without pans or trays — they are efficient, uniform, and flexible in operation. Improved furnaces of this type are described by Electric Furnace Co. Bulletin Ayx-30.

Alcoa Aluminum

The second edition of Aluminum Co. of America's 92-page book on "Alcoa Aluminum and Its Alloys" is packed full of valuable technical and practical data on all phases of the subject. Bulletin Ayx-54.

Maintenance by Welding

Industrial maintenance by Thermit welding is illustrated by actual applications to repair of street and railroad tracks, large machine parts, marine castings, crankshafts, and similar articles. Economy and permanence are featured. Metal & Thermit Co. Bulletin Ayx-64.

Turbo Compressors

The new items in Spencer Turbine Co.'s bulletin are a new and smaller "Midget" turbo for individual mounting, a single-stage line which effects new economies, and the gas-tight turbos for acid and explosive gases. Bulletin Mx-70.

Ultropak

Two booklets are issued by E. Leitz, Inc., one containing description and catalog of their Ultropak microscope equipment, and the other a series of quotations and illustrations from scientists using the method. Get both by asking for Bulletin Ayx-47.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Neophot

"Neophot" is the name of a new metallograph of radically new design and universal adaptability. A pamphlet distributed by Carl Zeiss, Inc., gives its applications and features and is well illustrated with beautiful samples of micrographic work. Bulletin Jx-28.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Carburizing Steel

High strength and ductility, forgeability, and machinability, combined with superior case carburizing properties, permit the attainment of maximum production with minimum cost. Such properties are obtainable in Jones & Laughlin's Jalcase steel. Bulletin Mx-50.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Recuperators

Results obtained with Carborundum Company's recuperators using Carbofrax tubes are fuel savings, closer temperature control, faster heating, and improved furnace atmosphere. Complete engineering data regarding application to various types of furnaces are given in Bulletin Fx-57.

Alloy Castings

A new bulletin on corrosion and heat resisting alloy castings is offered by Michiana Products Corp., manufacturers of Fire Armor and Zorite and other heat and acid resisting castings. Bulletin Jyx-81.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Kanthal Alloys

C. O. Jelliff Mfg. Co. offers a descriptive booklet on Kanthal alloys. Certain of these alloys may be used as resistance elements; others are for furnace parts or other heat resisting applications. Full details are given in Bulletin Je-78.

High Tensile Steels

Three types of high tensile steel particularly adapted to the transportation industries are described in a folder from U. S. Steel Corp. These are a chromium-copper-silicon steel for corrosion resistance, a medium manganese steel, and a strong structural silicon steel. Bulletin Mx-79.

Molybdenum in 1934

Climax Molybdenum Co. presents their annual book giving new developments in molybdenum, particularly as an alloy with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Dc-4.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Metal Progress
7016 Euclid Ave., Cleveland

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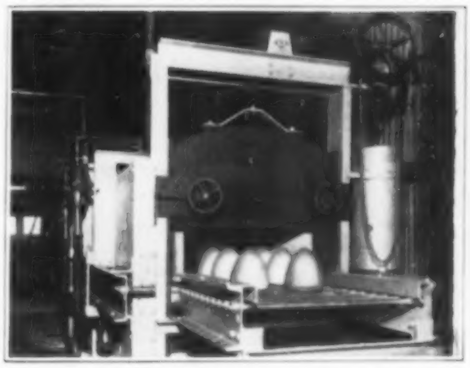
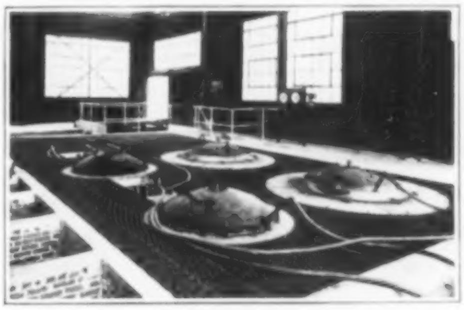
Clean and Bright Annealing Stampings

Ferrous and non-ferrous stampings in various shapes and sizes are clean and bright annealed, uniformly, economically and with minimum of labor in continuous, recuperative and roller hearth type furnaces we have built. Die life is prolonged and pickling is entirely eliminated. A roller hearth type furnace for this purpose is shown at right.—No trays are used—100% net material.



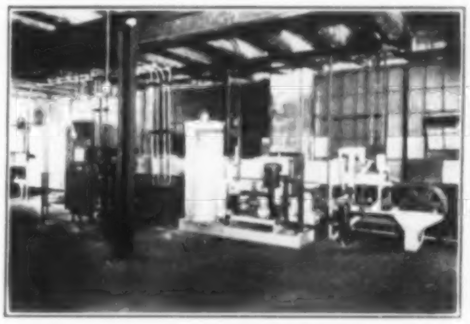
Bright Annealing Steel Wire

The illustration at right shows two pit type furnaces with Elfurno gas generator for annealing steel wire in coils. Advantages include: increased tonnage per pit, improved fuel economy, more uniformly annealed wire, lower maintenance cost, decreased annealing time and labor requirements, and maximum flexibility—will produce bright surface, semi-bright or otherwise as required.



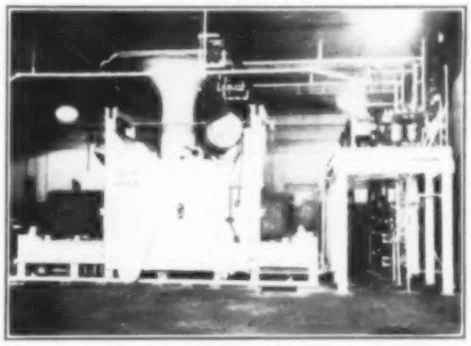
Copper Brazing and Soldering

Many products formerly difficult or expensive to make in one piece are now being made in several pieces and economically and securely joined in continuous type brazing or soldering furnaces. Intricate assemblies are loaded on a belt or conveyor, carried through the furnace and discharged completely joined—neater, stronger and more economically than by any other method. An installation for this purpose is shown at right.



Low Cost Production Nitriding

The illustration at right shows one of several installations of continuous, semi-continuous, and batch type nitriding furnaces we have made for the low cost production nitriding of miscellaneous parts. This furnace consists of a movable furnace chamber mounted on wheels and located above a stationary hearth on which the nitriding retorts are placed. The furnace can thus be operated over one or more retorts.



Annealing Strip in Coils

Coiled strip in various widths is annealed in this return recuperative furnace. The coils are loaded on trays and at regular intervals are automatically pushed through the recuperative chamber, into and across the heating chamber, and back through the recuperative chamber—the heat from the outgoing line preheats the ingoing material—saves fuel.

We build furnaces for every heating and heat treating process, for any product or production. No job is too large or to unusual. See the enlarged photographs of these and other outstanding installations in our Booth No. G-8 at the National Metal Exposition, Chicago.

THE ELECTRIC FURNACE CO.
SALEM, OHIO.

Fuel-Fired Furnaces — Electric Furnaces

Wherever Steel Is Made Big-End-Up Molds Do a Better Job!

Teeming a jag of Gathmann big-end-ups at Republic

NOBODY appreciates more than does the buyer that big-end-up methods of ingot production mean finer steels. And when sound, dependable steels are required, he specifies that they be made in accordance with recommended Gathmann practice.

The feature that contributes most to the quality of steels so produced is the big-end-up contour of the molds. This characteristic assures a degree of homogenity and soundness and a surface quality in the ingot and its product that are superior to anything possible with big-end-down methods.

Until quite recently, custom-made ingot molds were considered an unnecessary luxury in tonnage practice. Today, however, the largest plants in the world have their molds designed by Gathmann.

Big-end-up molds are recognized as necessary to economical production of all types of steel, not alone because of the better quality of the steel, but because of the high percentages yielded into first-grade products. Bloom yields from Gathmann type ingots average 82% or better in most practices.

Within the past few months several plants have made comparative tests with Gathmann big-end-up and standard big-end-down molds in casting all of the various types of steel which they produce. In the hundreds of heats (about 15,000 tons) made in these tests, the yields averaged better than three percent increase over the standard practice. This represents a tremendous saving that is particularly impressive when the improvement in the quality of the interior and surface of the product is taken into consideration.

Make your own comparative tests. You will find that modern Gathmann designs and methods will do for your practice what nothing else can — *they will assure dependability with high yields in steel of any specification.*

THE GATHMANN ENGINEERING COMPANY

DESIGNERS OF
INGOTS AND MOLDS SINCE 1909

BALTIMORE, MARYLAND